The Phenomenon of Soviet Science

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ABSTRACT

The grand "Soviet experiment" constituted an attempt to greatly accelerate and even shortcut the gradual course of historical development on the assumption of presumed knowledge of the general laws of history. This paper discusses the parts of that experiment that directly concerned scientific research and, in fact, anticipated or helped define important global changes in the functioning of science as a profession and an institution during the twentieth century. The phenomenon of Soviet, or socialist, science is analyzed here from the comparative international perspective, with attention to similarities and reciprocal influences, rather than to the contrasts and dichotomies that have traditionally interested cold war–type historiography. The problem is considered at several levels: philosophical (Soviet thought on the relationship between science and society and the social construction of scientific knowledge); institutional (the state recognition of research as a separate profession, the rise of big science and scientific research institutes); demographic (science becoming a mass profession, with ethnic and gender diversity among scientists); and political (Soviet-inspired influences on the practice of science in Europe and the United States through the social relations of science movement of the 1930s and the *Sputnik* shock of the 1950s).

SCIENCE AND SOVIET VALUES

The fact that the Soviet Communist regime placed extraordinarily high value and expectations upon science is, of course, rather well known. So much so, perhaps, that it has usually not been seen as a historical problem but has been taken for granted as something natural that does not ask for further discussion or inquiry. Behind the cover of obviousness, however, one can find a complex combination of historical choices and heterogeneous reasons—some ideological, some pragmatic, some accidental—that together may offer an explanation of why, among all the various political regimes and movements of the twentieth century, Communism, especially in its initial Soviet incarnation, happened to be the one most favorably predisposed toward science, believing most utterly, up to the point of irrationality, in science's power and value.

To begin with, the Soviets mounted their belief in science on top of a preexisting and rather high foundation. The cult of science flourished across Europe at the

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beginning of the twentieth century. It happened to be particularly prominent in the Russian empire, which had only recently embarked upon industrialization and modernization. Almost all parts of the political spectrum bought into it, although for different reasons. For Russian liberals, science was synonymous with economic and social progress; for the radical intelligentsia, including the yet utterly insignificant and marginal Bolsheviks on the very left, it was the closest ally of the revolution. Many among the monarchists, too, placed high hopes on modern science as a remedy for the country's relative economic backwardness vis-à-vis Germany, France, and Britain (other European countries rarely figured in the comparison). After the Great Reforms of the 1860s, they helped institutionalize science and promote the research imperative at Russian universities, hoping that at the very least it could distract unruly students from pursuing dangerous political temptations.[1]

World War I challenged, and in several important ways undermined, scientism in most of Europe. During the Great War, all major belligerent countries de facto recognized science as a matter of national concern and state policy by establishing special governmental offices to coordinate research with military needs. Yet in the wake of the European catastrophe—which is how the war began to be perceived ever more widely after its end, not only among the losers but often among the victors as well—many intellectual circles started doubting the common assumption of the preceding half century that material and social progress naturally followed from the development of science and technology. The thesis that knowledge results in vastly increased power reconfirmed itself strongly in the course of the military conflict, but this time in the form of much deadlier weapons. Unlike in the prewar decades, however, the great advances in positive knowledge and technical ingenuity produced not an amelioration of the human condition and social life but destruction, killing, and suffering on a previously unimaginable scale. These sacrifices appeared increasingly meaningless to the disillusioned postwar public, especially in the countries that had lost the war. The disaster and its absurdity made many feel that something was wrong with the previously optimistic worldview, with its uncritical belief in progress, reason, positive knowledge, civilization, and representative democracy.

Postwar economic troubles, revolutions, and counterrevolutions (and subsequently the Great Depression) further reinforced the public perception of a genuine crisis of modern society, which affected, at least temporarily during the interwar period, almost all countries with advanced science and technology. Various lines of thought disagreed with each other about which elements of the preceding worldview to retain and which to reject, to restrict in validity, or to mix in varying combinations with elements of an equally loose neoromantic worldview that could include the sense of tragedy, disruption, irrationality or mysticism, will, violence, and direct action. The spectrum of attitudes toward science reflected those disagreements. Some authors held science ultimately responsible for the European debacle, either as the social Darwinian inspiration for the war or as an utterly materialist, soulless Frankenstein leading humanity toward self-destruction. Others identified the main problem in the

[1] On Russian universities in the late imperial period, see G. I. Shchetinina, *Universitety v Rossii i ustav 1884 g.* (Moscow, 1976); and specifically on the institutionalization of research imperative, A. M. Korzukhina, *Ot prosveshcheniia k nauke: Fizika v Moskovskom i S.-Peterburgskom universitetakh vo vtoroi polovine XIX–nachale XX v.* (Dubna, 2006).

gap between humanity's advanced powers to manage the external world and its lagging capacity for moral and social restraint, and they called for a temporary moratorium on scientific research to give society a chance to catch up. However different and opposing these views were, they all implied some kind of malfunction in the relationship linking science and society.

Military defeat, collapse of imperial ambitions and empires themselves, and postwar economic meltdown made the feeling of crisis especially strong in Germany and parts of the former Austria-Hungary. German-speaking academics suffered a painful blow to their social prestige and economic prosperity. Formerly enjoying a dominant position in many branches of world science, they became international outcasts. Formerly envied by foreign colleagues for their privileged social status as civil servants and for the superior financial support they received from the German states, they saw both status and support severely undermined by postwar economic instability and hyperinflation. Alienated from the new democratic order, German professors nostalgically recalled the golden age of the prewar empire. While still adhering to the ideal of the "pure" and "apolitical" scholar, most tended to sympathize with reactionary opposition to the Weimar Republic. They accepted the conservative ideological argument that the mechanistic and materialistic science was at least partly to blame for the deep crisis in society. Talk about the "crisis in science"—meaning not only the undermined status of the academic profession but also serious doubts about fundamental methods and foundations of existing knowledge—became commonplace.[2]

Although Germany had been and continued to be, during the Weimar period, the source of much cultural inspiration in Russia, in their attitudes toward science, the Russian intelligentsia chose not to follow their neighbor's example, generally drawing instead almost the opposite conclusions from the traumatic war experience. It tended to see the source of the country's poor war performance and other social woes in the lack of, rather than in the excessive development of, science and technology and in insufficient support for them under the monarchical regime. The geologist and geochemist Vladimir Vernadsky, who during the war emerged as one of the main spokesmen for the academic community, was both reflecting upon and helping to define this general understanding when he argued in 1915 that

> regardless of the outcome of the war, both winners and losers will have to direct their thought toward further development of scientific applications to the military and navy affairs . . . One of the consequences—and also one of the causes—of Russia's economic dependence on Germany is the extraordinary insufficiency of our knowledge about the natural productive forces which Nature and History have granted to Russia. After the war of 1914–1915 we will have to make known and accountable the natural productive forces of our country, i.e., first of all to find means for broad scientific investigations of Russia's nature and for the establishment of a network of well equipped research laboratories, museums and institutions. . . . This is no less necessary than the need for an improvement in the conditions of our civil and political life, which is so acutely perceived by the entire country.[3]

[2] Paul Forman, "The Financial Support and Political Alignment of Physicists in Weimar Germany," *Minerva* 12 (1974): 39–66; Forman, "The Environment and Practice of Atomic Physics in Weimar Germany: A Study in the History of Science" (PhD diss., Univ. of California, Berkeley, 1968); Daniel J. Kevles, "'Into Hostile Political Camps': The Reorganization of International Science in World War I," *Isis* 62 (1971): 47–60.

[3] V. I. Vernadsky, *Ocherki i rechi*, 2 vols. (Petrograd, 1922) 1:5, 131–2, 140.

The end of the war, the revolution, and the civil war that followed did not invalidate his conclusions but greatly reinforced them not only in Vernadsky's own eyes, but also in the eyes of his political enemies, the Bolsheviks. Belief in science remained one of the few things intelligentsia on the opposite sides of revolutionary barricades still agreed about. In the course of the civil war the new Bolshevik government embraced and endorsed Vernadsky's vision of science and in 1922 reprinted as extremely important the collection of his addresses and proposals regarding science policy, including the ones quoted above.

No longer marginal and unimportant, but successfully clinging to their claim to rule the country and guide the revolution, the Bolsheviks drew similar lessons from the war and strengthened them with their own peculiar combination of ideological, cultural, and pragmatic reasons. From their intellectual roots—the Enlightenment, classical Marxism, and the cultural tradition of the intelligentsia—the Bolsheviks inherited a perception of science as an important ideological ally and a major force of not merely economic but also social and political progress. They expected the rational scientific worldview to unseat the power of religion and superstition over the minds of the people. At least in the Communists' own minds, the belief in the power of science as a panacea for many social problems substituted for the religious belief per se or in any case rose to similar levels of intensity and devotion. Similar perceptions and high expectations were also extended to social sciences and the humanities, in part because of the wider meaning of the words for "science" in Russian (*nauka*) and German (*Wissenschaft*), which embraced all fields of scholarship. Marxism, too, belonged to science in this wider sense, as it modeled itself upon natural science and applied the naturalistic method of explanation to the study of human society and history. Its conclusions were therefore, to Russian Marxists, as certain as scientific truths about nature. This linguistically reinforced linkage between science and Marxism helped further support their perceived alliance and mutual prestige in the Bolshevik worldview.[4]

In contrast to Germany, in Russia the prestige of science did not suffer but rose significantly during and after the war and the revolution. The Bolsheviks, in particular, placed the blame in the science-society equation squarely on society—more precisely, capitalist society. The European crisis, in their interpretation, was that of the bourgeois social order and capitalist economy, which misused knowledge toward inhumane goals. Science participated in the crisis only insofar as it was bourgeois, that is, adversely affected by irrational and mystical intellectual currents, militarism, and nationalism. Hence the motto "crisis of science" became in the Soviet translation the "crisis of bourgeois science." Under socialist principles, the Bolsheviks claimed, "all the marvels of technology, all the accomplishments of culture will belong to everyone, and never again will the human mind and ingenuity be turned into instruments of violence and the means of exploitation."[5] After attaining political power, Bolsheviks in Soviet Russia not only maintained but further promoted the intelligentsia's virtually unrestricted cult of science and technology as the key to achieving their primary economic objectives—industrialization and modernization of the country.

[4] P. V. Alekseev, *Revoliutsiia i nauchnaia intelligentsia* (Moscow, 1987); Helena Sheehan, *Marxism and the Philosophy of Science: A Critical History; The First Hundred Years* (Amherst, N.Y., 1993).

[5] III Vserossiiskii s'ezd sovetov rabochikh, soldatskikh i krest'yanskikh deputatov, 10–18 (23–31) yanvaria 1918 (citation from K. M. Bogoliubov, ed., *Lenin i KPSS o razvitii nauki* [Moscow, 1981], 96).

In "The Immediate Tasks of the Soviet Power," written in March 1918, a few months after the revolution, Lenin contemplated the challenges arising before the Communist Party as the ruling party. He acknowledged the lack of scientific expertise and technical cadres among the Bolsheviks as the main obstacle to the difficult task they faced of running the country and its economy and suggested a policy of cooperation and compromise with predominantly noncommunist and nonsympathizing "bourgeois intelligentsia"—educated experts of all kinds, including scientists, engineers, medical doctors, educators, and military professionals. He even included some "former industrial chiefs, former bosses and exploiters," who, according to Lenin's plan, "must take on the role of technical experts, managers, consultants and advisers."[6] He went so far, he admitted, as to compromise Communist principles by proposing to pay "bourgeois experts" excessive salaries because their collaboration was an absolutely necessary condition for the Soviet regime's economic and political survival and a key to building socialism.

As a result of this policy, throughout the 1920s, many nonparty scientists and engineers were invited to join (and did so) various offices of the Soviet state to work in responsible positions alongside Communist officials. A monarchist general and chemistry professor, Vladimir Ipatieff, directed the nationalized chemical industry and military-oriented research. A liberal, Vladimir Vernadsky, watched the Bolshevik government adopt and implement his vision of ambitious geologic exploration, in particular of the country's remote northeastern territories. A Communist and electrical engineer, Gleb Krzhizhanovsky, drafted the plan for national electrification—GOELRO—an ambitious technocratic project that was enthusiastically adopted and promoted by the Bolshevik government and became a political symbol of the entire revolutionary experiment. Lenin's related slogan, "Communism is the Soviet power plus the electrification of the entire land!" metaphorically recognized the dual nature of the early Communist regime as grounded upon a political pact between the party and "bourgeois intelligentsia."[7]

The strengthened cult of science and technology emerged as a kind of national consensus, stretching across the Red-White divide and uniting the intelligentsia of practically all political stripes amid violent political disagreements of the revolutionary era. The revolution and the civil war inflicted upon Russian scientists enormous material hardships, but at the same time, they saw their social prestige and political importance skyrocket to previously unthinkable levels. Scientists and engineers in postrevolutionary Russia achieved an unprecedented direct access to political power, perhaps the closest approximation in real historical time of the utopian project of "philosopher-guardians" in Plato's *Republic*. Over the next ten years, although noncommunist, they became de facto an active part of the governing elite and influenced many large and small policies of the early Soviet regime and day-to-day management of the nation's economy. Together with the Bolsheviks, "bourgeois experts" invented and built up the new Soviet state as a nationwide technocratic, modernizing project.

[6] V. I. Lenin, "Pervonachal'nyi variant stat'i "Ocherednye zadachi sovetskoi vlasti," in *Polnoe sobranie sochinenii*, vol. 36 (Moscow 1969), 137–42.

[7] Jonathan Coopersmith, *The Electrification of Russia, 1880–1925* (Ithaca, N.Y., 1992); V. N. Ipatieff, *The Life of a Chemist* (Stanford, Calif., 1946); A. V. Kol'tsov, *Sozdanie i deiatel'nost' Komissii po Izucheniiu Estestvennykh Proizvoditel'nykh Sil Rossii, 1915–1930 gg.* (St. Petersburg, 1999); S. A. Fediukin, *Velikii oktiabr' i intelligentsiia: Iz istorii vovlecheniia staroi intelligentsii v stroitel'stvo sotsializma* (Moscow, 1972).

In the process of which, they also embarked upon creating a new type of infrastructure for scientific research and development.

SCIENCE AS PROFESSION

On a rainy day in October 1912, a royal cavalcade descended on a quiet Berlin suburb and brought Kaiser Wilhelm II to the inauguration of two chemical institutes, the first ones of the newly organized research society, the Kaiser-Wilhelm-Gesellschaft. The society, funded jointly by the state and private industry, planned to establish several such institutes, each one for an exceptional scientist of "genius" rank (according to the so-called Harnack Principle), who would be freed from teaching as university professors and granted the privilege of engaging in full-time research in the direction of his choice with the help of the most up-to-date equipment and research assistants. Proud of their leadership in many fields of science, German professors convinced the state to grant science one extra level of support and protection.[8]

Even before that development, the rest of the world of science envied Germany's generously funded laboratories and university institutes. Rumors about the latest plan reached Russia at a particularly critical time, when Moscow University, the oldest and largest university in the country, half destroyed itself in turmoil. As a result of a student political meeting and protest, and government intrusion into the prerogatives of the university council, about a quarter of all professors and privatdocents resigned in protest against the state violation of the principle of academic autonomy. In typically inflated intelligentsia rhetoric, biology professor K. A. Timiryazev used and exaggerated the news from Germany to contrast the obscurantism of the Russian government with the enlightened recognition of the value of science in the "entire civilized world." Describing as "backward" the fact that in Russia "all science [is] concentrated in universities," he called on Russian society to liberate science from both teaching obligations and the state by creating privately funded institutes for research.[9]

The idea attracted an enthusiastic following among the Russian academic intelligentsia, and by 1917, the Moscow society founded by the resigned professors had raised funds and established two institutes, one for biology and one for physics. The revolution and the civil war, however, channeled development in a somewhat different direction. On the one hand, "liberation from the state" was arrested as the revolutionary Bolshevik government nationalized private foundations and their research institutes. On the other hand, the socialist state proved much more willing to satisfy scientists in the second half of their agenda, the "liberation from teaching." The Bolsheviks supported the scientists' project of separate research institutes not only because it helped them win scientists as collaborators in their larger social experiment but also because they had much less respect and tolerance for the same academics in the role of university professors. As quickly became apparent, university teachers and administrators were subject to stricter political demands and controls than were employees at the new research institutes. This discrepancy, and the availability of new,

[8] Jeffrey Johnson, *The Kaiser's Chemists: Science and Modernization in Imperial Germany* (Chapel Hill, N.C., 1990).

[9] K. A. Timiriazev, "Novye potrebnosti nauki XX veka i ikh udovletvorenie na zapade i u nas" (1911), in *Nauka i demokratiia: Sbornik statei 1904–1919 gg.* (Moscow, 1963), 56–66.

attractive jobs, soon led to a sizable portion of the Russian scientists being employed primarily, if not exclusively, in research rather than in teaching positions.[10]

The profile of the new institutions reflected the experience of the Great War as well as specific Marxist ideas about science, which at the time sounded dangerously radical and provocative to much of the public. In particular, Bolshevik authors insisted that scientific thought, even at its most abstract, had originated from and stayed linked to the practical, especially economic, activity of the people. They thus categorically rejected the ideology of German and British (as well as the majority of Russian) academics that privileged and separated "pure science" from "applied" research and technology. To Marxists, the concept of pure science bordered on nonsense, as even the most fundamental science was worthy of its name only if it had potentially useful applications, at least in the long-term perspective. While offering scientists increased public support for research, the Bolsheviks required in return that investigations be targeted toward social and economic goals of society and the state.

With this purpose in mind, Communists rejected the principle of the autonomy of the academic profession as a closed, self-governing corporation. Instead, they promoted the ideal of science as a public profession or branch of civil service, supported by public funds and consciously serving social needs. Orientation toward producing useful knowledge required that the main directions of research and the distribution of resources for science would be rationally "planned" via institutions of the state. Such ideas were not unique to Russia or to the Bolsheviks: during the war, scientists in other belligerent countries formulated similar, if less radical and demanding, proposals in response to the need to mobilize science for wartime use. As the military conflict subsided and science returned to peacetime existence, such ideas were largely abandoned or, as in Germany, restricted by conditions of military defeat. In Soviet Russia, however, they did not dissipate after the war but were taken up and carried much further by the revolution, declared essentially socialist, and promoted by the revolutionary government as the program for the ensuing period of peace.

The Russian academic intelligentsia shared part of the above ideas. Like their wartime peers in other countries, Russian professors tried to make their knowledge useful during World War I but became painfully aware of the absence of working links between Russian academic science and industry. They developed proposals for radical reform in the country's scientific infrastructure, including calls to turn science toward practical tasks facing the nation. As the first step toward fulfillment of this goal, Vernadsky established in 1915 the Commission for the Study of Natural Productive Forces at the Petrograd Academy of Sciences, thus reorienting the academy away from its century-long preference for pure science. After the revolution, the commission and its practical economic orientation provided the basis for the first collaboration agreement between the Academy and the Bolshevik government.[11]

The new regime particularly welcomed the turn of science toward economically important research. Several dozen research institutes were established during the civil war in fields such as optics, roentgenology and radiology, aero- and hydrodynamics,

[10] Alexei Kojevnikov, "The Great War, the Russian Civil War, and the Invention of Big Science," *Science in Context* 15 (2002): 239–75.

[11] V. I. Vernadsky, "Ob izuchenii estestvennykh proizvoditel'nykh sil Rossii (Dolozheno v zasedanii Fiziko-Matematicheskogo otdeleniia 8 aprelia 1915 g.)," in *Ocherki i rechi* (cit. n. 3), 1:5–25; Kol'tsov, *Sozdanie i deiatel'nost' Komissii po izucheniiu estestvennykh proizvoditel'nykh sil Rossii* (cit. n. 7).

plant breeding, rare metals, and radio. Russia's economy suffered much more severely as a result of the civil war than the economies of Austria and Germany did from postwar inflation, but the rise in the social value of science compensated somewhat for the material losses. Thanks to this preferential treatment, science actually managed to advance despite poverty and starvation. During the civil war, scientists received rations essential for their physical survival amid hunger and devastation, while many of the newly established research institutes became administratively independent from the universities. The Bolsheviks were particularly enamored with the fields that combined revolutionary utopia with utilitarianism—the promise of achieving some grand practical, even if only remotely possible, goal on the basis of some modernist, revolutionary novelty, such as radioactivity, X-rays, aviation, or genetics. The corresponding state-funded institutes were often multidisciplinary and combined basic investigations in advanced science with the design and production of sophisticated technology, a "symbiosis, . . . a fusion of 'pure' science, technology, and engineering," that several decades later began to be called "big science."[12]

More important than a significant increase in size, a new definition of the research worker distinguished the new institutes from the preceding generation of university laboratories. Up until then, the usual position for a scientist was that of a university professor or assistant involved in undergraduate teaching. Employment at the new institutes created a large group of salaried scientists and research engineers who were professionally occupied full time with scientific research, training of advanced students, and the development of new technologies, with no or only incidental obligations to teach undergraduates. Effectively, the Soviet government lifted scientific research up to the status of a new mass profession and a branch of civil service, recognized as socially important and supported in its own right, rather than indirectly via higher education, by generous public funds.

Under the Bolshevik rule, scientists lost much of their autonomy and independence but acquired more social prestige and de facto influence on politically important decision making. The Soviet regime valued science more highly and allocated it a proportionally larger share of the national income than did contemporary governments in economically better developed and more prosperous countries. It strongly opposed the ideology of pure science, promoting instead the ideal of science as potentially usable—even if not always immediately applicable—knowledge about the world. The Soviets particularly excelled in their efforts to popularize scientific knowledge among the widest possible segments of the population and make science education available to broad masses.[13] They strongly pressured the existing scientific cadres into doing research related to economic and societal needs and, with this purpose in mind, emphasized the need for rational organization and planning of scientific enterprise. At least some of the above features of the Soviet model appealed to outside observers, especially on the political left, and influenced reforms in other countries. As early as the 1920s, the Nationalist (Guomindang) government in China established scientific institutions modeled upon the Soviet example. During the 1930s, scientist

[12] Dominique Pestre and John Krige, "Some Thoughts on the Early History of CERN," in *Big Science: The Growth of Large-Scale Research*, ed. Peter Galison and Bruce Hevly (Stanford, Calif., 1992), 93.

[13] James T. Andrew, *Science for the Masses: The Bolshevik State, Public Science, and the Popular Imagination in Soviet Russia, 1917–1934* (College Station, Tex., 2003); J. G. Crowther, *Soviet Science* (London, 1936).

activists in western Europe started demanding a similar public recognition for science from their own governments.

In Europe, the ideal of pure, disinterested research remained largely unchallenged in the scientific community until the 1930s. The Great Depression subjected to critical scrutiny not only the failures of capitalism but also the role of science in it, as overproduction of goods and unemployment were blamed, at least in some circles, on technological advances achieved through science. But the very scene of a society in deep crisis and of human misery alone made many scientists, regardless of their political sympathies, think more about social problems and the possible role of science in solving them. Even the British Association for the Advancement of Science, whose long-standing principle was to avoid becoming involved in issues of politics and government, agreed in 1933, after two years of hesitation and deliberation, that scientists should no longer isolate themselves from general affairs and added to its traditional fields of concern the study of the social impact of science.[14]

A crucial encounter occurred, however, in July 1931 at a rather unlikely and otherwise insignificant event, the Second International Congress of the History of Science and Technology in London. Without much advance warning, a Soviet delegation that included a high-ranking politician and several leading scientists and Marxist philosophers arrived at the congress. At a specially arranged session, Nikolai Bukharin, Boris Hessen, and others presented an unprepared audience with a different discourse on science, which to some of the attendees sounded like a Martian language and to others like a revelation. According to the Soviet view, science, past and present, was not just the intellectual pursuit of a few selected great minds but an intelligent answer to social and economic problems and a method of solving them. It did not have to be individualistic and uncoordinated but could be planned, consciously directed at socially useful goals, and pursued in collective work. Instead of isolating themselves from society, scientists could and should consciously engage in it. Immediate converts to this view formed a closely knit group of left-wing scientists, which included, among others, J. D. Bernal, Hyman Levy, J. B. S. Haldane, and Joseph Needham, who subsequently became principal activists in the social relations of science movement in Great Britain.[15]

Later in 1931, Bernal, by then a member of the Communist Party, traveled to the Soviet Union to become acquainted firsthand with the Soviet organization of science. "Is it better to be intellectually free but socially totally ineffective or to become a component part of a system where knowledge and action are joined for one social purpose?" he asked his British colleagues rhetorically, convinced by then that the time of haphazard, individualistic, and small-scale science had already passed and that research itself had entered an industrialized, massive stage. Beginning in 1932, Bernal and other left-wing scientists became the dominant voice in the Association of Scientific Workers and popularized Marxist views in general and Marxist vision of science in particular among British academics and the public. Besides raising scientists' social consciousness, the association pushed for an increase in

[14] William McGucken, *Scientists, Society, and State: The Social Relations of Science Movement in Great Britain, 1931–1947* (Columbus, Ohio, 1984); J. G. Crowther, *The Social Relations of Science* (London, 1941).

[15] N I. Bukharin et al., *Science at the Cross Roads*; *Papers Presented to the International Congress of the History of Science and Technology Held in London from June 29 to July 31, 1931, by the Delegates of the USSR*, 2nd ed. (London, 1971).

state allocations for research and for a tighter relationship between scientists and the government.[16]

The Soviet example was also important in France, where, beginning in 1930, Jean Perrin led a similar campaign to recognize scientific research as a separate profession in civil service, while the Communist Paul Langevin supplied the movement with information about Soviet science. Socialist electoral victories in 1932, and the united Popular Front government in 1936, brought scientists' political allies into power. The Caisse Nationale de la Recherche Scientifique (CNRS), established in 1935 in a merger of two modest predecessors, assumed the leading role in distributing funds for research. Irène Curie, and after her Jean Perrin, accepted an appointment in the Popular Front government to the newly created position of deputy minister for scientific research and managed to increase significantly state allocations for research. By 1939 CNRS was supporting, fully or partly, approximately 600 salaried researchers, about half of the academic scientists in France.[17]

By Bernal's estimate, the United Kingdom was spending about 0.1 percent of its national income on scientific research in the mid-1930s, compared with 0.8 percent in the USSR, for which much better statistical data was also collected and published at the time.[18] In 1937, the British government turned down Bernal's memorandum, written on behalf of the Parliamentary Science Committee, proposing reform in the national funding of research. As the war drew closer, however, even the Royal Society and the liberal opponents of Marxism agreed with the demand for government coordination of science, while Bernal and his supporters dropped their previous disdain for military research.[19] With the start of the war, the Communist Bernal entered government service and played a key role in numerous military planning and research committees, seeing in the wartime mobilization of science a realization of his Marxist proposals of the 1930s. When British scientists working on the development of radar technology decided to meet regularly for informal discussions with representatives from different branches of the military, they even called their gathering the "Sunday Soviet."[20]

The political awakening of scientists in the United States came mainly through the British example but with considerable delay. In 1937, Robert K. Merton still observed that "attempts for concerted action by English scientists contrast sharply with the apathy of scientists in this country." The mood changed over the following two years, with the establishment of two activist organizations: the liberal and antifascist American Committee for Democracy and Intellectual Freedom, and the more radically leftist adaptation of its British prototype, American Association of Scientific Workers. Ultimately, in the United States, as in Britain, the war emergency forged an otherwise improbable alliance between normally anticommunist military leaders,

[16] J. D. Bernal, "Science and Society," *Spectator*, 11 July 1931, 43–4, reprinted in Bernal, *The Freedom of Necessity* (London, 1949), 334–9; Gary Werskey, *The Visible College: The Collective Biography of British Scientific Socialists of the 1930s* (New York, 1978).

[17] Spencer Weart, *Scientists in Power* (Cambridge, Mass., 1979); Mary Joe Nye, "Science and Socialism: The Case of Jean Perrin in the Third Republic," *French Historical Studies* 9 (1975), 141–69.

[18] Chris Freeman, "The Social Function of Science," in *J. D. Bernal: A Life in Science and Politics*, ed. Brenda Swann and Francis Aprahamian (London, 1999), 101–31.

[19] Maurice Goldsmith, *Sage: A Life of J. D. Bernal* (London, 1980); Neal Wood, *Communism and British Intellectuals* (New York, 1959).

[20] Guy Hartcup, *The Challenge of War: Britain's Scientific and Engineering Contributions to World War Two* (New York, 1970), 24, 52.

such as General Leslie Groves, and left-wing scientists with Communist connections, such as J. Robert Oppenheimer, whose respective visions regarding the proper relationship between science and the government became compatible and overlapping to a significant degree. They worked jointly on large-scale military research projects, collaborated in the establishment of the institutions of big science, and brought about federal support for big science and the recognition of it by society and the state.[21]

SOCIAL CONSTRUCTIVISM

Marx's classical critique of bourgeois ideology argued that political, economic, philosophical, and legal doctrines reflected and represented social and class interests. At the same time, Marx generally stopped short of applying a similar analysis to the doctrines of the natural sciences. This concession to the dominant positivistic mood of the era somewhat contradicted the general Marxist assertion that science, including the most abstract concepts of mathematics, was as much a human activity as other forms of knowledge and had its origin in human life and needs.[22] Profiting from the early twentieth-century intellectual turmoil and epistemological critiques of the foundations of science by Ernst Mach and Henri Poincaré, Aleksandr Bogdanov carried the Marxist thought one logical step further in his 1918 brochure *Socialism of Science*, by introducing a perspective on science that has since become known as "social constructivism."[23]

According to Bogdanov, science, understood as an "organized social and economic experience" of the laboring humanity, reflected the needs and concerns of society, not merely the natural world. Thus it was not accidental, for example, that modern European science appeared during the sixteenth and seventeenth centuries in parallel with the rise of new capitalist societies and new economic demands of manufacturing, navigation, trade, and warfare. New scientific knowledge, such as Newtonian mechanics, in turn helped advance capitalist technology and production further, into the industrial age. The nature of scientific knowledge and activity, therefore, should be understood as closely linked with technology and industry, not separated from them. In the course of the nineteenth century, as the bourgeoisie, according to Marx, was losing its revolutionary and historically progressive role, so were the bourgeois features of contemporary science. This resulted in science's increasing abstraction, the rise of the ideology of "pure" science, science's inaccessibility to the masses and alienation from the concerns and practices of working classes, and its subordination to market relations. Bogdanov envisioned that the rise of a new, socialist society would bring along a serious reform in the existing body of scientific knowledge, a change in the viewpoint that he compared to the shift in the point of view required by the Copernican revolution in astronomy. Novel social and labor practices would

[21] Peter J. Kuznick, *Beyond the Laboratory: Scientists as Political Activists in 1930s America* (Chicago, 1987); Alexei Kojevnikov, "The Making of the Soviet Bomb and the Shaping of Cold War Science," in *Reappraising Oppenheimer: Centennial Studies and Reflections*, ed. Cathryn Carson and David A. Hollinger (Berkeley, Calif., 2005), 129–45. As Kuznick describes, however, American engineers and especially physicians preceded scientists in developing interest toward the Soviet experience starting in the early 1930s, particularly attracted to the system of socialized medicine.

[22] For a summary of Marx's sociology of science, see Michael Mulkay, *Science and the Sociology of Knowledge* (London, 1979), chap. 1

[23] A. A. Bogdanov, "Sotsializm nauki" (1918), reprinted in Bogdanov, *Voprosy sotsializma: Raboty raznykh let* (Moscow, 1990), 360–76.

also enrich science with this important new knowledge, "proletarian science," in Bodganov's terminology.[24]

Trotsky and Lenin rejected talk about "proletarian science" as premature and dangerously radical, denouncing it as damaging the party's pact with bourgeois specialists. For them, it was more important to recruit the already existing science and expertise into the immediate service of socialist construction.[25] Bolsheviks continued to criticize Bogdanov and reject the term "proletarian science," even though, upon closer examination, they were in agreement on most other basic values, such as demands for science to deliver practical results and be accessible to the masses. The subsequent mainstream Communist vision of science adhered unwaveringly to the principle of scientific materialism—a belief that science delivers truth, or at least relatively objective truth, about nature. At the same time, their discourse combined the former principle with important concessions toward "social constructivism"—that *nauki* (sciences in the wide sense) in general and the natural sciences in particular were subject to social and ideological influences, all the way up to the very content of scientific knowledge—but avoided explicit contradictions between the two approaches. According to Soviet Marxist views, it was quite appropriate that their time—the period of great social crises and revolutions—resulted in a crisis of "bourgeois" science and inspired revolutionary developments in the basic foundations of knowledge. The real-life difficulty was that the two aspects were so closely intertwined within the contradictory developments in contemporary science that it was hard to distinguish precisely which scholarly claims could be dismissed as reflecting the dead-end crisis of bourgeois thought and which ones needed to be supported as important and promising revolutionary breakthroughs.

Take, for example, Einstein's theory of relativity, which met an enthusiastic early welcome in revolutionary Russia, with the majority of scientists, avant-garde artists, and the public welcoming it as an overturning of the existing conceptual order, an accomplishment in science just as radical and revolutionary as the Russian Revolution's overturning of the existing order in society. The 1922 discovery by the Soviet mathematician Aleksandr Friedmann that the universe governed by Einstein's equations is not stable but can explode, collapse, and be born again, in a process subsequently called the big bang, also appealed, in a metaphorical way, to the revolutionary mentality and the existential experience of those who survived a social explosion of cosmological magnitude. But the same relativity theory had been inspired by and laden with the philosophical ideas of neopositivism, such as those by Ernst Mach, which appeared to contradict dialectical materialism, the Marxist philosophy of nature, and scientific materialism in general.[26] The contradiction could be resolved by following the example of Lenin's 1909 book *Materialism and Empirio-Criticism*, which attempted a demarcation between, on the one hand, novel and positive scientific developments and, on the other hand, often "wrong" and "idealistic" philosophical conclusions attached to them or derived from them by bourgeois ideologues and scientists. Adopting this approach, future president of the Soviet Academy of Sciences physi-

[24] On Bogdanov as philosopher, see: Arran Gare, "Aleksandr Bogdanov's History, Sociology, and Philosophy of Science," *Studies in History and Philosophy of Science* 31 (2000): 231–48; Zenovia A. Sochor, *Revolution and Culture: The Bogdanov-Lenin Controversy* (Ithaca, N.Y., 1988).

[25] Leon Trotsky, "What Is Proletarian Culture and Is It Possible?" (1923), http://www.marxists.org/archive/trotsky/works.

[26] Alexander Vucinich, *Einstein and Soviet Ideology* (Stanford, Calif., 2001).

cist Sergei Vavilov could, within the same line of discourse, praise Einstein's relativity as the great revolutionary achievement in science, criticize Einstein's philosophical "mistakes," and proclaim that for better methodological and heuristic guidance in their search for true knowledge, natural scientists should cling to the philosophy of dialectical materialism.[27]

Modern (Mendelian) genetics and eugenics provided yet another controversial case of novel scientific developments mixed with corrupting ideological influences that were difficult to separate from one another. Both fields, related by their common foundation in the concept of "hard" heredity and overlapping communities of scholars, initially received an enthusiastic welcome in the revolutionary Russia of the 1920s. As information about eugenics' close association with racism in the United States and the related practices of forced sterilization gradually became known in the USSR, eugenics increasingly came to be regarded as so thoroughly corrupted by bourgeois ideological influences that it abandoned the objective path of true science. The Soviets were first to come to a completely negative verdict about eugenics—as early as 1931—and to abandon all research conducted under this label. The close association of geneticists with the eugenics movement also partially undermined their reputation in the eyes of Soviet authorities. Elsewhere, eugenics continued to grow, inspired in particular by the example of legislation adopted in 1933 by Nazi Germany and partially imitated in a number of other countries in Europe and North America. It did not become discredited internationally until 1945, after shocking revelations about Nazi medical crimes; it quickly faded away, at least in name. Having effectively banned eugenics more than a decade earlier, the Soviet Union overreacted to the new revelations. In 1948, the agronomist Trofim Lysenko won political support for his claim that Mendelian genetics, too, was ideologically and scientifically untenable and racist and had to be abandoned in favor of his own, idiosyncratic, genetics based on the concept of "soft," or environmentally flexible, heredity. It would take the Soviet establishment sixteen years to officially recognize the latter decision as a serious mistake.[28]

Even before 1945, Nazi Germany provided another striking example of political influences corrupting science that inspired strong international reactions. The 1933 law banning non-Aryans and political opponents of the Nazi regime from the civil service resulted in massive dismissals of Jewish and socialist academics. In the first wave of firings, more than 1,000 university teachers, including some 300 professors, lost their jobs. The refugee crisis, the rising international tide of Fascism, and the looming threat of a new war moved the positions of liberal and leftist scientists in Europe closer to each other. Many on the liberal side who formerly subscribed to the ideal of the apolitical scholar saw science threatened by the Nazi assault on its core values and consequently became more active politically. Previously reluctant government officials recognized the threat of a possible war and moved increasingly toward a more active science policy that would allocate additional funds and coordinate

[27] S. I. Vavilov, "Novaia fizika i dialekticheskii materialism," *Pod Znamenem Marksizma*, 1939, no. 12:27–33.

[28] Diane B. Paul, *Controlling Human Heredity, 1865 to the Present* (Amherst, N.Y., 1995); Robert Proctor, *Racial Hygiene: Medicine under the Nazis* (Cambridge, Mass., 1988); Mark Adams, ed. *The Wellborn Science: Eugenics in Germany, France, Brazil, and Russia* (New York and Oxford, 1990). On Soviet genetics and the Lysenko case, see the article by Nils Roll-Hansen in this volume and the extensive literature cited there.

research with anticipated military needs. And many scientists, such as Bernal and his leftist allies, who had once strongly denounced the application of science to warfare, started seeing their most pressing social responsibility in turning their research to the service of defense. The emerging collaboration of the liberal and the Left in common opposition to Fascism came to be known, in politics, as the Popular Front. In France, united antifascist scientists helped create the alliance named Comité de Vigilance des Intellectuels Antifascistes, which unified parties left of center in joint defense of democracy against both foreign and homegrown Fascism. In discourse about science, the trend corresponding to what in politics was represented by the Popular Front developed under the slogan "science and democracy."

Scientists all across the Popular Front spectrum, from liberal to Communist, started pushing forward the idea that science and political democracy were closely linked and that both had to be defended against Fascism. From New Zealand, the Austrian refugee Karl Popper argued that scientific "progress depends very largely on political . . . democracy," as both are essentially grounded in freedom of critical discourse. In England, Bernal saw science as the crucial ally in the looming global struggle between "democratic and Fascist states," adding that "in its endeavour, science is communism" because in it "men have learned consciously to subordinate themselves to a common purpose, without losing the individuality of their achievements." Merton in the United States, hoping to prove that "democratic order is integrated with the ethos of science," defined the latter as consisting of four "institutional imperatives—universalism, communism, disinterestedness, organized skepticism." And in the USSR, Sergei Vavilov of the Soviet Academy of Sciences predicted that the allied victory over Fascism would result in "strengthening the role of science and democracy in the life of peoples," adding that "science serves progress only when combined with democracy." "Democracy" in all these pronouncements was understood in its antifascist meaning, rather than in the later cold war interpretation of it as anticommunist.[29]

The unrecognized father of Marxist social constructivism, Bogdanov, died in Moscow in 1928 in a scientific experiment on blood transfusion he conducted upon himself.[30] Soviet obituaries praised him as the organizer of the national system of blood transfusion but continued to criticize him ideologically. They were loath to acknowledge that Bogdanov's social constructivist argument continued in Soviet discourse about science, without, however, any reference to the author and any mention of his discredited notion of proletarian science. In 1931 social constructivism made its way to the West through the famous (or infamous, depending on the interpretation) paper by Boris Hessen, "The Socio-Economic Roots of Newton's Principia," delivered, along with other Soviet talks, at the London Congress of the History of Science.[31] It was subsequently picked up by the Marxist social relations of science movement of the 1930s, was strongly opposed as "externalism" by the anti-Marxist school of "internal logic of the development of science" during the cold war, and eventually

[29] Karl R. Popper, *The Open Society and Its Enemies* (Princeton, N.J., 1950), 404; Robert K. Merton, "A Note on Science and Democracy," *Journal of Legal and Political Sociology* 1 (1942), 115–26; J. D. Bernal, *The Social Function of Science* (London, 1939), 331; S. I. Vavilov, *Sovetskaia nauka na novom etape* (Moscow, 1946); David A. Hollinger, *Science, Jews, and Secular Culture* (Princeton, N.J., 1998).

[30] V. N. Yagodinsky, *Aleksandr Aleksandrovich Bogdanov (Malinovsky), 1873–1928* (Moscow, 2006).

[31] Loren R. Graham, "The Sociopolitical Roots of Boris Cherenkov Hessen: Soviet Marxism and the History of Science," *Social Studies of Science* 15 (1985): 705–22.

mutated into the currently more familiar version of social constructivism of the New Left around 1970. The latter version has since evolved quite far from the original Marxist one, both by greatly widening the "social" away from the narrow primacy of the "economic" and, more importantly, by dropping the scientific materialism part of the discourse, which for the old Left was and remains more important than the "constructivist" part. Some modern-day authors may even be loath to acknowledge the original Marxist roots of the "social constructivist" concept, hoping to keep them entirely invisible.

AFFIRMATIVE ACTION

The career of Pavel Cherenkov can serve as a guide through the Soviet policies of reverse privileges in education that encouraged representatives of formerly discriminated groups to enter the ranks of the scientific profession. Born in 1904 to a peasant family in southern Russia, with eight siblings from his father's two marriages, Cherenkov grew up in poverty. At the age of thirteen, he started working as a manual laborer, after completing just two years of elementary schooling. A Soviet secondary school opened in the village in 1920, after the revolution and the civil war, which allowed Cherenkov to resume his education while continuing to earn a living by occasional work at a grocery store. The radical reform of the entire educational system enacted by the revolutionary Bolshevik government in 1918 opened the door to further schooling.[32]

In their attempts to democratize access to higher education, the Bolsheviks did not remain satisfied with merely annulling the formal discriminatory barriers of gender, ethnicity, and religion. They tried to compensate actively for economic disadvantages and earlier discrimination by adopting a system of preferential treatment for potential students from underrepresented groups—workers, peasants, women, and ethnic minorities—broader and more radical than the analogous one currently known in the United States as "affirmative action." The measures included free tuition, quotas, and stipends for low-income students. The number of colleges and universities greatly expanded, and special crash courses, called *rabfaks* (workers' faculties), opened within all universities to provide a quick functional education substitute for students who had not had an opportunity to complete secondary schooling. These faculties and their students helped Communists and Communist sympathizers to seize administrative and political control over universities.[33]

Last but not least, the Commissariat of Enlightenment either abolished or softened the formal requirements for school certificates, diplomas, and degrees necessary for advancing from one educational level to another. It became possible, in principle, to enroll in a university without formal graduation from a high school, start a graduate program without fully completing an undergraduate education, and be hired as a professor without a PhD degree or equivalent. Many future prominent Soviet scientists

[32] On early Soviet education see: M. N. Pokrovsky, "Narodnoe prosveshchenie i vysshaya shkola," in *Izbrannye proizvedemiya*, vol. 4 (Moscow, 1967), 457–551; William G. Rosenberg, ed., *Bolshevik Visions: First Phase of the Cultural Revolution in Soviet Russia* (Ann Arbor, Mich., 1984).

[33] Sheila Fitzpatrick, *The Commissariat of Enlightenment: Soviet Organization of Education and the Arts under Lunacharky, October 1917–1921* (Cambridge, UK, 1971); Terry Martin, *The Affirmative Action Empire: Nations and Nationalism in the Soviet Union, 1923–1939* (Ithaca, N.Y., 2001); V. V. Mavrodin, ed., *Na shturm nauki: Vospominaniya byvshikh studentov fakul'teta obshchestvennykh nauk Leningradskogo universiteta* (Leningrad, 1971).

of the Cherenkov generation skipped one or another of these formal steps (but not all of them altogether) while embarking on their academic careers. Cherenkov, too, took advantage of promotional opportunities available for lower-class students. In 1924, apparently without earning a high-school diploma or completing secondary education, he enrolled in the Pedagogical Department of Voronezh State University.[34]

Graduation from a provincial university in 1928 enabled Cherenkov to become a teacher of physics and mathematics at an evening school for workers in the small town of Kozlov. The following year, however, a new and more radical stage of the cultural revolution broke out in the Soviet Union. For the first twelve years following the revolution, the Communist reforms were gradually enacted in higher education, but scientific institutes continued to remain the province of "bourgeois experts." Yet more militant factions among the Communists had worried all along about the power of experts and the possibility that they would take advantage of scientifically uneducated Soviet officials. In their worst case scenarios, instead of being politically guided by Soviet commissars, the bourgeois intelligentsia would exert its own political influence over Soviet decision making under the guise of scientific advice. Tensions exploded in 1929, with the start of the all-out industrialization campaign and the crash collectivization in agriculture.

The party annulled its pact with bourgeois experts and set out to replace them with a new generation of "red experts," who would ideally combine proper professional qualifications with sincere devotion to socialist values. The massive industrialization made the already acute shortage of technical cadres even more critical, yet despite this, many senior scientists and engineers educated prior to the revolution were demoted or purged on accusations of disloyalty and sabotage. Many more, however, declared themselves reformed into earnest supporters of socialism. And in the meantime, an even larger cohort of fresh graduates with loyal backgrounds was being hastily educated in engineering colleges and universities, whose numbers quadrupled.[35] This time, the cultural revolution spread wider, affecting not only colleges but also research institutions and their staffs. Renewed and intensified attempts to attract lower-class students, women, and minorities into the ranks of scientific researchers extended affirmative action to the greatly expanded *aspirantura*, or graduate studies programs.

A thorough statistical study of the nation's scientific cadres in 1930 represented the existing situation as follows. There were approximately 50,000 positions whose holders engaged in scientific activities of some sort, about 18,000 of them primarily research positions. In the meantime, the study acknowledged, the goal of "planned development of scientific thought in the USSR require[d] in the shortest time possible, to attract new and massive human contingents." Between 1917 and 1929, the proportion of women among scientific cadres had risen from 11.7 percent to 18.8 percent (to 23.3 percent among graduate students). The study mentioned the problem of the glass ceiling and the unequal representation of women in various fields of research, with the highest percentages achieved in philosophy, pedagogy, and medicine (38.9, 36.8, and 35.7 percent, respectively). Half of all scientists were concentrated in Moscow and

[34] A. N. Gorbunov and E. P. Cherenkova, eds., *Pavel Alekseevich Cherenkov: Chelovek i otkrytie* (Moscow, 1999).

[35] Sheila Fitzpatrick, *Education and Social Mobility in the Soviet Union, 1921–1934* (Cambridge, UK, 2002); Kendall E. Bailes, *Technology and Society under Lenin and Stalin: Origins of the Soviet Technical Intelligentsia* (Princeton, N.J., 1978).

Leningrad, but conscious efforts were under way to expand both geographic and ethnic diversity, by educating and promoting members of underrepresented minorities. In the Ukrainian Soviet Socialist Republic, for example, the proportion of Ukrainians among scientists (46.8 percent) was still significantly lower than that among the republic's population as a whole (80.0 percent), whereas the corresponding numbers for Russians and Jews in Ukraine were 27.6 versus 9.2 and 20.8 versus 5.4 percent, respectively.[36]

Cherenkov's biography once again reflected the major trends and events of the period. His peasant father was exiled as a kulak during village collectivization in 1930, while his father-in-law, a professor of Russian literature at Voronezh, was dismissed as a bourgeois professor and sent to work in a labor camp. His relatives' political troubles and possible suspicions they could have thrown on him did not prevent Pavel from being accepted, the very same year, to one of the country's most prestigious graduate programs at the Physicomathematical Institute of the USSR Academy of Sciences in Leningrad. Most likely, his peasant background worked as a strong argument in favor of admission, outweighing his relatives' problems. Soviet educational policies at the time still did not recognize academic degrees such as the PhD. Instead of writing a thesis, the job of an aspirant was to learn the trade of scientific research while working as a junior apprentice alongside established scientists.

Cherenkov's adviser, Sergei Vavilov, had the background, education, and looks of a typical bourgeois professor, but he always maintained a very loyally Soviet posture in his public pronouncements. Under Vavilov's direction, Cherenkov started working diligently on luminescence induced by radioactive gamma rays and in 1933 discovered a faint background glow, which turned out to be a heretofore unknown kind of radiation. Now called the Cherenkov radiation and used for detecting high-speed particles in accelerators and cosmic rays, it brought Cherenkov worldwide recognition, a 1946 Stalin Prize (jointly with Vavilov), and a 1958 Nobel Prize in Physics. (Vavilov had died earlier and therefore could not be nominated.)[37]

The Soviet ideologically shaped solution to the extreme shortage of technical specialists in the 1930s included a dramatic expansion of public funding to education at all levels, the abolishment of tuition along with all other fees for higher education, a radical increase in the number of specialized technical schools, and an unprecedented broadening of the demographic base of science and engineering students, with massive promotion of representatives of lower classes, women, and ethnic minorities. Ten years later, in the course of World War II, that system of training engineering cadres stood its ultimate test by proving its ability to design advanced technological weapons and outproduce Nazi Germany in tanks and aircraft. After the end of the war, the Soviet educational model exerted strong international influence, first of all on the countries of Eastern Europe, and not only on the initiative of local Communists. In 1945, Hungarian biochemist and Nobel laureate Albert Szent-Györgyi traveled to the Soviet Union to familiarize himself with the Soviet organization of science. After returning from this trip, he embarked on the transformation of Hungarian science along similar lines, with research institutes independent from the universities

[36] O. Yu. Shmidt and B. Ya. Smulevich, eds., *Nauchnye kadry i nauchno-issledovatel'skie uchrezhdeniya SSSR* (Moscow, 1930), 4, 17, 19, 49–52, 59.

[37] I. M. Frank, "A Conceptual History of the Vavilov-Cherenkov Radiation," *Soviet Physics Uspekhi* 27 (1984): 385–95.

and with massive specialized training of scientists and engineers. Other countries in Eastern Europe enacted similar reforms.[38]

The largest reform of this kind—some argued the largest program of technology transfer in history—developed between the Soviet Union and the People's Republic of China. In 1949, Mao Zedong ordered a reorientation of Chinese science and education exclusively toward the Soviet example. During the subsequent ten years, more than 10,000 Chinese students and scientists went to the USSR for training, and approximately the same number of Soviet experts visited and worked in China as teachers and consultants at hundreds of industrial and academic projects. Existing academic institutions in China underwent reform, and new ones came to be established based on Soviet blueprints. An entire generation of Chinese scientists was trained and a new scientific infrastructure built before 1960, when the relations between the two Communist parties worsened and, in response to Chinese accusations of "revisionism"(that is, preferring peaceful coexistence with American imperialists to world revolution), Nikita Khrushchev ordered the complete withdrawal of Soviet experts from China.[39]

In the cold war United States, the National Manpower Council and the Commission on Human Resources and Advanced Training had been issuing warnings since the early 1950s that "Russia is already far advanced on a program of mass education, and by selecting the most competent pupils at each school level is educating greater and greater numbers of students through technical institutes, college and the university."[40] The issue caught national attention, however, only after the spectacular launch of *Sputnik* in October 1957. American politicians and the public entered the debate about how the country managed to lose its scientific and technological supremacy: in 1945 they had felt comfortable in seeing the Soviets as technologically far inferior; fifteen years later, the USSR had caught up with the United States by testing atomic weapons, had come even in developing thermonuclear ones, and had actually surpassed America in missile design.

In the ensuing soul searching, some lessons and measures were easier to accept and execute than others. A further increase in government funding for scientific research was no longer politically problematic: that familiar and accepted lesson had been assimilated from the wartime experience and the Manhattan Project. This time the financial flow jumped another level, not only through military but also through civilian, or ostensibly civilian, channels such as the National Science Foundation and NASA, the newly established, Soviet-inspired government agency. The offices distributing this flow abandoned the once functional categorization of science into pure and applied research, just as the Soviets had done thirty years earlier, at a time

[38] Gábor Palló, "Accommodation to a New Center: Albert Szent-Györgyi's Trip to the Soviet Union," in *Travels of Learning: A Geography of Science in Europe*, ed. Ana Simões, Ana Carneiro, and Maria Paula Diogo (Boston Studies in the Philosophy of Science, vol. 233) (Dordrecht, Netherlands, 2003), 329–42.

[39] Chu-yuan Cheng, *Scientific and Engineering Manpower in Communist China, 1949–1963* (Washington, D.C., 1965); Baichun Zhang, Jiuchun Zhang, and Fang Yao, "Technology Transfer from the Soviet Union to the People's Republic of China, 1949–1966," *Comparative Technology Transfer and Society* 4 (2006): 105–71.

[40] Commission on Human Resources and Advanced Training, *America's Resources of Specialized Talent: A Current Appraisal and a Look Ahead; The Report of the Commission on Human Resources and Advanced Training* (New York, 1954); National Manpower Council, *A Policy for Scientific and Professional Manpower: A Statement by the National Manpower Council* (New York, 1953).

of equally dramatic increases in state support for science and technology. The mentality of scientists on the receiving end followed along, and the label "pure science" gradually died out in the vocabulary of American scientists. The old ethos requiring scientists to be ashamed of taking out patents started to look obsolete, and the road toward the later commercialization of science opened up.

The main bottleneck and real difficulty in connection with the *Sputnik* crisis concerned scientific manpower, for the increase in funding could not be quite matched by a corresponding increase in the training of qualified personnel, and making higher education free proved to be outside the limits of political possibility in the United States. Still, *Sputnik* helped invigorate previously stalled proposals for reform in American education through federal support. The National Defense Education Act, passed in 1958, reflected political compromise: ideological and legal conditions restricted the use of federal funds at the undergraduate level and below, effectively directing it to the graduate level and higher, with serious implications for the resulting "brain drain."

Importing qualified manpower from overseas ultimately proved to be a politically and ideologically easier solution than fixing remaining deficiencies in education at home. The memory of the special role played by foreign émigrés in the atomic bomb project was still very vivid. Changes in U.S. immigration policies—turning away from earlier racial quotas toward preferential acceptance of trained specialists—started in the 1950s and continued under the Immigration and Nationality Act of 1965. The proportion of professional and technical workers among new immigrants had increased to 17.9 percent by 1960 and to 29.4 percent by 1970, more than twice the share of such workers in the total U.S. population. By 1966, the share of foreign-born PhDs in American science constituted roughly 12 percent and continued to grow.[41]

In the early post-*Sputnik* years, about half of scientific immigration came to the United States from Europe, especially from Britain and Germany. At one point, the British government pronounced the very existence of the nation's missile program to be in danger because so many of its participants had taken jobs with NASA. A 1962 Royal Society report cried out about the loss of British scientists to U.S. immigration and coined the term "brain drain." But Britain was actually in the middle of the food chain: although it lost scientists to the United States, it also acquired them from other countries, especially from its former colonies. The dynamics of the brain market soon shifted toward bringing a proportionally larger share of immigrant scientists to the United States from India, Taiwan, South Korea, and later other regions, more arriving for graduate study in the United States than with PhDs in hand. The new arrivals, and the affirmative action policies demanded by the civil rights movement, which were similar to but more limited than earlier Soviet efforts, challenged the still widespread racist and sexist stereotypes about scientists and ultimately changed the demographics of the scientific profession in the United States. Today, a large portion of the presently retiring generation of scientists in the West and those who are replacing them in academic positions owe the existence of their jobs to the launch of the little aluminum sphere in 1957. The fact that science now is not only much larger

[41] Barbara Barksdale Clowse, *Brainpower for the Cold War: The Sputnik Crisis and National Defense Education Act of 1958* (Westport, Conn., 1981); Laura Fermi, *Illustrious Immigrants: The Intellectual Migration from Europe, 1930–41* (Chicago, 1968).

but also much more multiracial and multicultural than fifty years ago is probably the most important, if often overlooked, consequence of the *Sputnik*-enticed public awareness about the Soviet Union's massive training and employment of scientists with diverse ethnic, gender, and class backgrounds.[42]

CONCLUSIONS

In developing the understanding of Soviet science presented above, I tried to overcome a trio of mutually connected obstacles that have stood in the way of that understanding. The first one may be called methodological; it included an attempt to understand historical specificity without recourse to divisions into polar categories and oppositions. Instead, a style of analysis was adopted that uses as its tools interactions, connectivity, and mutual influences. The second was political, the prevalence of cold war stereotypes in academic discourse about all matters Soviet, which did not go away with the end of the cold war and the Soviet Union itself. This discourse had encouraged on both sides of the iron curtain, and to a large extent continues to encourage even now, exactly the opposite: a dualistic kind of analysis with a set of polar categories—East-West, socialist-capitalist, totalitarian-democratic, and such—postulated from the start and then providing the main reference frame for sorting out the particulars and for understanding the complexities and paradoxes of historical developments. The third may be called either linguistic or the problem of vision. The dualistic mentality instinctively tries to hide away analogous trends and dependencies, to make invisible mutual influences and borrowing, even to the point of deliberately attaching different linguistic labels to identical phenomena (for example in the official names of the professions of the "cosmonaut" and the "astronaut") lest the naïve audience be confused by their similarity. Parting with such instincts, ingrained in one's mind by more than a half century of public use, may not be an easy matter; in the above discussion I tried to battle, perhaps not entirely successfully, with them in my own thinking and to develop at least a partially alternative vision.

The alternative presents the phenomenon of Soviet science with its peculiarities and distinctiveness, but without making it the alienated "other." Instead, the Soviet case is interpreted as a part of general international developments in twentieth-century science, influenced by some, transforming and influencing in return some others. This essay specifically concentrated on those aspects of the story that made the Soviet example important elsewhere and, in a wider sense, also for "us" today, as a part, however invisible, of contemporary scientific practices. One such important twentieth-century trend is the political recognition of vast state involvement in supporting and directing scientific research. The trend appeared inconclusively in many countries during the course of WWI, demanded particularly strongly by Russian scientific intelligentsia prior to the revolution, subsequently adopted by the Bolsheviks and implemented on a massive scale within the Soviet experiment in the 1920s, then taken up by leftist scientists in Europe in the 1930s, and generally, perhaps permanently, accepted, even by anticommunists, as a lesson learned from the Second World

[42] The Royal Society, *The Emigration of Scientists from the United Kingdom to the United States: A Report of the Committee Appointed by the Royal Society* (London, 1963); Herbert G. Grubel and Anthony Scott, *The Brain Drain: Determinants, Measurement, and Welfare Effects* (Waterloo, Ontario, 1977); Bradley W. Parlin, *Immigrant Professionals in the United States: Discrimination in the Scientific Labor Market* (New York, 1976).

War. A related and similarly important trend involved public recognition of scientific research as a profession, which took different forms in different countries but brought about an establishment of a new infrastructure—separately funded and governed institutions for research—and a new social group, that is, salaried scientists and engineers concerned primarily with research rather than teaching.

The increased social and political importance of science inspired, in a way, a reconsideration of the general theoretical understanding of the relationship between science and society. The Soviet Marxist discourse on the matter produced an analysis that has subsequently evolved into what is currently known under the term "social constructivism." At the same time, the enormous expansion of the scientific profession in the course of the twentieth century depended upon radical changes in its demographics, namely its opening up to representatives of previously underrepresented and discriminated groups, by gender, class origin, ethnicity, or race. Such policies, pioneered in the interwar USSR, were an essential part of the Soviet effort to educate within a short period a massive contingent of professional scientists and engineers. The message of success in outproducing other scientifically advanced countries in scientific education was brought out, powerfully, by the launch of *Sputnik* in 1957. This event caused, in turn, a similarly radical expansion of the scientific profession internationally, first of all in the United States, with corresponding demographic changes in the racial and gender representation in science.

One result of this study, potentially troubling to some, is a gradual uncovering of the degree to which some features that were once thought to belong specifically to Soviet science or ideologically promoted by Communism, have contributed to, evolved into, or become part of today's generally accepted scientific practices and ostensibly anticommunist worldview. Some of them have achieved this status by the way of conscious or unconscious borrowing, others by osmosis, rivalry, negation, transformation, or simply renaming. This interconnectedness was part of a general process that changed science, and the world, in the course of the twentieth century. The realization of such a worst case nightmare would have certainly upset Senator Joseph McCarthy and others like him, who smelled and feared "communist infiltration, communist indoctrination, communist subversion and the international communist conspiracy." To the degree that we no longer share the senator's mindset and paranoia, and can treat Communism as a historical event, there is no need to remain in a state of denial.