Russian & Soviet Science and Technology

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FOREWORD

This is the fourth guide in the series Teaching the History of Science: Resources and Strategies, published under the auspices of the Committee on Education by the History of Science Society. These guides, written by specialists, are intended for the use of historians of science as well as general historians and any other teachers who wish to begin to revise a history of science course or to incorporate new topics into an existing course. The guides published in the Newsletter will be published, with other essays, as a pamphlet in mid 1989. Earlier guides appeared in the July 1986, April 1987, and Supplement 1988 issues of the Newsletter. The editorial board for each guide is drawn from the Society's Committee on Education. The committee welcomes comments on the value of these guides, as well as on suggested topics for future guides.

INTRODUCTION

The history of science and technology in Russian and the Soviet Union is a field of study that is underdeveloped in the West, and good books on the subject in English or other West European languages are correspondingly rare. Nonetheless, a number sources exist, as the following bibliography illustrates. Because of the youth of the field and the difficulty in gaining access to archives, the quality of existing works is uneven and the coverage spotty. In recent years this situation has begun to improve. There is a small but perceptible growth of interest in the history of Russian and Soviet science and technology in research universities. At present a handful of American universities–MIT, Harvard, Pennsylvania, Northwestern, Georgetown, Columbia, Arizona, Oregon State–offer occasional courses on the subject, but as yet no more than three or four senior American historians are working full-time in the field.

The scarcity of good books in Western languages is not a result of the inherent unimportance of the subject. Today the Soviet Union has the world's largest community of scientists and engineers, exceeding that of the United States by almost a third, and this community has deep historical roots. Scientists and engineers in the tsarist empire had earned world fame for their achievements. Among the best known were Nikolai Lobachevskii, the first person to develop non-Euclidean geometry; Dmitrii Mendeleev, creator of the periodic table of the chemical elements; and Ivan Pavlov, the noted physiologist and the first Russian to receive a Nobel Prize.

Most Americans are unaware that the development of science in Russia is approximately as long as it is in the United States. Mikhail Lomonosov and Benjamin Franklin, two of the most significant figures in the early history of science in the two countries, lived at the same time and even did research on some of the same topics, including electricity. Professional societies in the two countries, such as the American Chemical Society and the Russian Physico-Chemical Society, were founded in approximately the same period. Indeed, America and Russia in the eighteenth and nineteenth

centuries shared geographic and geopolitical characteristics that influenced science in the two countries in similar ways: both were outside the center of world science at that time, Western Europe, and both were busy exploring vast virgin lands, an activity that led to particular strengths in such fields as botany, geology, and soil science.

In some other important respects, however, the scientific traditions of the two countries differ. Many observers have noted that Russia and the Soviet Union have been strongest in fundamental science, particularly in mathematics and theoretical physics (what some people call “blackboard science”) and weakest in applied science and engineering. American strength, on the other hand, has, until recently, been in the applied sciences.

Another distinguishing characteristic is that scientists and government officials in Russia have always considered science to be closer to politics than have their counterparts in the United States. The tsarist government feared that Russian scientists who studied in Western Europe would bring home not only scientific knowledge but also Western political theories in conflict with those of the supporters of the Romanov autocracy. For their part, Russian scientists usually considered themselves part of the intelligentsia, with all the oppositional implications that this term conveys. Like the government censors, Russian scientists often made no clear distinction between science and politics. By the late nineteenth century many Russian scientists believed that rational scientific knowledge automatically led to criticism of state politics and the state-supported form of the Russian Orthodox faith. Out of this inter-mixing of science and politics arose many clashes, such as the refusal of tsarist censors to publish Ivan Sechenov’s work on physiological reflexes on the ground that it supported atheism.

After the Russian Revolution the new Soviet government adopted a very positive attitude toward science but retained the view that science and politics are interwoven. Almost every Soviet book on the history of science in the USSR contains some reference to the official view that science and Soviet socialism are mutually Supportive. The outside observer might note that the Soviet government has indeed strongly supported science, but that the history of Soviet science contains episodes such as the Lysenko affair, illustrating that the influence of politics on science can be harmful as well as beneficial.

Counterbalancing the scarcity of good books on the history of Russian and Soviet science in Western languages is a large body of literature on the subject published in the Soviet Union in recent decades. The center of this research is the Institute of the History of Science and Technology of the Academy of Sciences of the USSR, located in Moscow. In just one series of monographs entitled Scientific-Biographical Series (Nauchno-Biograficheskaia Seriia) this institute has sponsored several hundred biographies of Russian and Soviet scientists, almost all of them written in Russian. The Academy of Sciences has also put out an overview in English of work in Russian: The History of Science: Soviet Research, 2 vols. (Moscow, 1985). Although this literature can be used profitably by the Western scholar who knows the Russian language, much of it is flawed by being written from an internalistic and nationalistic point of view. Some of the best Soviet pieces in English on the history of Soviet science can be found in the Dictionary of Scientific Biography, where significant deceased Russian and Soviet scientists are described. Users of this source should be sure to check the supplementary volumes for articles written after the editors decided to drop the rule that only Soviet authors could write about Soviet scientists.

GENERAL HISTORIES

The best overview in English of the history of science in Russia before 1917 is Alexander Vucinich's two-volume study Science in Russian Culture (Stanford, Calif.: Stanford Univ. Press, 1963, 1970). A treatment of the Soviet period, somewhat incomplete in its coverage, is Zhores Medvedev, Soviet Science (New York: Norton, 1978). A topic in the history of Soviet science that touches on almost all scientific fields is the role of Marxism. For the 1920s and early 1930s the basic work on this topic is David Joravsky, Soviet Marxism and Natural Science (New York: Columbia Univ. Press, 1961). For the role of Marxism in later periods see Loren R. Graham, Science and Philosophy in the Soviet Union (New York: Knopf 1972). The latter book has been expanded and updated to cover events up to the middle 1980s in Graham's Science, Philosophy, and Human Behavior in the Soviet Union (New York: Columbia Univ. Press, 1987).

The most important single institution in Russian and Soviet science has been the Academy of Sciences, founded in 1725 according to a plan worked out by Tsar Peter the Great. Since the Academy has traditionally encompassed all fields of knowledge, including both the natural and social sciences, histories of the Academy are virtually general histories of science in Russia, although they do not give much attention to university or industrial research. Two sources treating the early history of the Academy in the tsarist period are Alexander Lipski, "The Foundation of the Russian Academy of Sciences," Isis, 1953, 44:349-354 and Ludmilla Schulze, "The Russification of the St. Petersburg Academy of Sciences and Arts in the Eighteenth Century,Ó British Journal of the History of Science, 1985, 18:305-335. A work that provides much general information on the Soviet period is Alexander Vucinich, Empire of Knowledge: The Academy of Sciences of the USSR (1917-1970) (Berkeley: Univ. California Press, 1984).

A crucial time for the Academy came in the late 1920s, when it was thoroughly restructured by Soviet authorities. This episode is described in Loren R. Graham, The Soviet Academy of Sciences and the Communist Party, 1927-1992 (Princeton, N.J.: Princeton Univ. Press, 1967); and in Aleksey E. Levin, "Expedient Catastrophe: A Reconsideration of the 1929 Crisis at the Soviet Academy of Science," Slavic Review 1988, 47(2):261-279. A later, much less traumatic, reform of the Academy is described by Graham in "Reorganization of the USSR Academy of Sciences," in Soviet Policy-Making, edited by Peter Juviler and Henry Morton (New York: Praeger, 1967), pp. 133-162.

Although the Academy has dominated Russian and Soviet science, other scientific societies also existed. A description of the fate of the prerevolutionary societies after the Revolution is James Swanson's "The Bolshevization of Scientific Societies in the Soviet Union: An Historical Analysis of the Character, Function, and Legal Position of Scientific and Scientific-Technical Societies in the USSR, 1929-1936" (PhD. diss., Dept. of History, Indiana Univ., 1968).

One of the most distinctive features of Soviet science is the organization of research in the institute system, an innovation adopted in the 1920s. Although there are research institutes in all scientific nations today–and there were quite a few even in the 1920s-the term scientific-research institute (nauchno-issledovatel'skii institut) has a stature and a meaning in the Soviet Union that it does not have in any Western country. Almost all outstanding scientists and engineers in the Soviet Union are members of an institute or have connections with one. The establishment and early history of this system are described in Mark Adams, "Science, Ideology, and Structure: The Kortsov Institute, 1900-1970," in The Social Context of Soviet Science, edited by Linda Lubrano and Susan Gross Solomon (Boulder, Colo.: Westview Press, 1980), pp. 173-204; Paul Josephson, "The Ioffe Physico-Technicall Institute and the Birth of Soviet Physics" (Ph.D. diss., Massachusetts Institute of Technology, 1986) and Loren R. Graham, "The Formation of Soviet Research Institutes: A

Combination of Revolutionary Innovation and International Borrowing," Russian and Slavic History, edited by I Karl Rowney and G. Edward Orchard (Columbus, Ohio: Slavica, 1977), pp. 49-75. The work of an important institute with origins long before the Soviet government arose is described in Stanwyn G. Shener, The Komarov Institute: 250 Years of Russian Research (Washington, D.C.: Smith- sonian Institution Press, 1967).

Another striking feature of the history of Russian science, at least in the nineteenth century, is the role of women. Russian women were among the first in the world to receive doctorates in mathematics, physiology, zoology, chemistry, and other fields, as discussed in Ann Hibner Koblitz, "Science, Women, and the Russian Intelligentsia: The Generation of the 1860s," Isis, 1988, 73:208-226.

HISTORIOGRAPHY

The best overview of Western works on the history and social study of science and technology in the Soviet Union is Susan Solomon, "Reflections on Western Studies of Soviet Science," in The Social Context of Soviet Science (ed. Lubrano and Solomon; see Section I), pp. 1-29. Articles describing the evolution of Soviet interpretations of the history of science are David Joravsky, "Soviet Views on the History of Science," Isis, 1955, 46:3-13; and Alexander Vucinich, "Soviet Marxism and the History of Science," The Russian Review, 1982, 41:123-142.

One Soviet contribution to historiography–nor in fact itself on the history of Russian or Soviet science–caused a great controversy over methodology and interpretation in the field as a whole. In 1931, at the Second International Conference of the History of Science in London, the Soviet physicist and historian Boris Hessen presented a paper on Isaac Newton that is often considered the most influential paper in the externalist interpretation of the history of science. By externalism we usually mean the explanation of the evolution of science in terms of economic and social forces rather than on the basis of experimental evidence and logical deduction. Paradoxically, after Hessen called for externalist interpretations of the history of science, most Soviet works in the field have been internalist in nature. Although not on Soviet science, his paper must be seen in the context of Soviet events that fundamenrally affected its form and substance. This context, largely ignored in the West, is explored in Loren Graham, "The Socio-Political Roots of Boris Hessen: Soviet Marxism and the History of Science," Social Studies of Science, 1985, 15:705-722.

The social study of science and technology in the Soviet Union is usually termed naukovedenie, or "science studies." The nature and evolution of this field are explored in Linda Lubrano, Soviet Sociology of Science (Columbus, Ohio: American Association for the Advancement of Slavic Studies, 1976); and Yakov Rabkin, ÒNaukovendenie: The Study of Scientific Research in the Soviet Union," Minerva 1976, 14:61-78.

Mathematics

It is in mathematics that Russia and the Soviet Union have made the greatest contributions. Today the Soviet Union is a world power in mathematics. Indeed, Moscow probably has the greatest concentration of talent of any city. The main competitor is no doubt Paris, since mathematicians in

the United States, another leader in mathematics in the last generation, are more widely distributed geographically.

This great tradition in mathematics dates back to Leonhard Euler and Jakob Bernouilli in the early eighteenth century, both of whom did important work while living in Russia. N.I. Lobachevskii, M.V. Ostrogradskii, and P.L. Chebyshev in the nineteenth century solidified the reputation of Russia in mathematics. By the early twentieth century Russian mathematicians were working at the leading edge of mathematics in many areas: Chebyshev and A. A. Markov in the theory of numbers and probability; V. A. Steklov and A. N. Krylov in differential equations; D.F. Egorov, K.A. Andreev, and A. K. Vlasov in geometry; D.A. Grave, S. O. Shatunovskii, and F. E. Molin in algebra; N. N. Luzin in theory of functions; and many others. In the later Soviet period outstanding mathematicians are far too numerous to name, but they include L.M. Gerfand, A. N. Kolmogorov, A. Ia. Khinchin, S.N. Bernshtein, N.N. Bogoliubov, L.V. Kantorovich, L.S. Pontriagin, L.R. Shafarevich, S. L. Sobolev, and I. M. Vinogradov.

Unfortunately, the importance of the history of Russian and Soviet mathematics is poorly reflected in English-language sources. Not even Lobachevskii, the creator of non-Euclidean geometry, is the subject of a full biography in English. V.F. KaganÕs N. Lobachevsky and His Contribution to Science (Moscow: Foreign Languages Publishing House, 1957) is perhaps the source most often cited, but it is clearly inadequate. Alexander Vucinich has explored some of the nontechnical aspects of Lobachevskii's life in his "Nikolai Ivanovich Lobachevskii: The Man Behind the First Non-Euclidean Geometry," Isis, 1962, 53:465-481. The best source on the circumstances of the creation of Lobachevskii geometry is a senior thesis by Gregory Crowe, "The Life and Work of Nikolai Ivanovich Lobachevsky: A Study of the Factors Leading to the Discovery and Acceptance of the First Non-Euclidean Geometry" (Harvard Univ., 1986).

A happy exception to the dearth of English-language materials on the history of Russian and Soviet mathematics is Anne Hibner Koblitz's biography of the first significant woman mathematician of modern times, A Convergence of Lives: Sofia Kovalevskaia: Scientist, Writer, Revolutionary (Boston: BirkhBuser, 1983). Biographical material is also available on Nikolai Luzin, a founder of the twentieth-century "Moscow School" of mathematics, in two articles: Esther Luzin R. Phillips, "Nicolai Nicolaevich and the Moscow School of the Theory of Functions," Historia Mathematica 1978, 5:275-30; and Allen Shields, ÒYears Ago: Luzin and Egorov," The Mathematical lntelligencer, 1987, 9(4):24-27.

Biological Sciences

The Russian and Soviet contribution in biology is less significant than that in mathematics, but the available materials are, somewhat paradoxically, more numerous. Topics that have particularly attracted the attention of Western historians are the reception of Darwinism in Russia in the nineteenth century and the Lysenko affair in the twentieth; these both relate to a third topic that has attracted scholars: genetics.

On Darwinism, the most discriminating and thorough work is Daniel Todes, Darwin without Malthus: The "Struggle for Existence" and Russian Evolutionary Thought in the Nineteenth Centuty (Oxford: Oxford Univ. Press, 1989). Some of Todes's main ideas can be found in his "Darwin's Malthusian Metaphor and Russian Evolutionary Thought, 1859-1917," Isis, 1987, 78:537-551; and his

ÒV. O. Kovalevskii: The Genesis, Content, and Reception of His Paleontological Work," Studies in the History of Biology, 1978, 2:99-165. The profound influence of the Russian tradition of morphology on the formulation of Soviet Darwinism is the subject of Mark Adams, "Severtsov amd Schmalhausen: Russian Morphology and the Evolutionary Synthesis," in The Evolutionary Synthesis: Perspectives on the Unification of Biology, edited by Ernst Mayr and William Provine (Cambridge, Mass.: Harvard Univ. Press, 1980), pp. 193-225. A more general treatment of Darwinism in Russia is Alexander Vucinich, Darwin in Russian Thought (Berkeley/Los Angeles: Univ. California Press, 1989). James Allen Rogers has three articles on the subject: "The Reception of Darwin's Origin of Species by Russian Scientists," Isis, 1973, 64:484-50; "Charles Darwin and Russian Scientists," Russian Review, 1960, 13(4):371-38; and "Russian Opposition to Darwinism in the Nineteenth Century," Isis 1974, 65:487-505. Another source on this topic is Sarah Swinburne White, "The Reception in Russia of Darwinian Doctrines Concerning Evolution" (PhD. diss., Univ. London, 1968). Also useful is George L. Kline, "Darwinism and the Russian Orthodox Church," in Continuity and Change in Russian and Soviet Thought, edited by Ernest J. Simmons (New York: Russell & Russell, 1967), pp. 307- 328.

One proponent of a characteristically Russian modifocation of evolutionary theory is Peter Kropotkin, known for his work on "mutual aid" within species. There is no biography of Kropotkin that takes full account of both his biological and political interests, but his political views and activities are analyzed in Martin Allen Miller, Kropotkin (Chicago: Univ. Chicago Press, 1976). Also worthy of examination is James Alien Rogers, "Prince Peter Kropotkin, Scientist and Anarchist: A Biographical Study of Science and Politics in Russian History" (PbD. diss., Harvard Univ., 1957).

A more widely known–indeed, notorious–figure in Russian biology is T. D. Lysenko. The most complete work on Lysenko is David Joravsky, The Lysenko Affair (Cambridge, Mass.: Harvard Univ. Press, 1970). Another important work, written by a Soviet biologist who became an opponent of Lysenko, is Zhores Medvedev, The Rise and Fall of T D. Lysenko (New York: Columbia Univ. Press, 1969). More idiosyncratic is Dominique Lecourt, Proletarian Science? The Case of Lysenko translated by Ben Brewster (London: NLB, 1977). For a study of late Lysenkoism see Mark Adams, "Genetics and Molecular Biology in Khrushchev's Russia" (Ph.D. diss., Harvard Univ., 1973), a source that also contains much information on biochemistry.

That the field of population genetics was largely established in Soviet Russia before Lysenko's rise to power is the significant conclusion of a series of articles by Mark Adams. Two were published in the Journal of the History of Biology: "The Founding of Population Genetics: Contributions of the Chetverikov School, 1924-1934," 1968, 1(1):23-39 and "Towards a Synthesis: Population Concepts in Russian Evolutionary Thought, 1925-1935," 1970, 3(1):107-129. Adams discusses how the term gene pool derives from a Russian concept in "From Gene Fund to Gene Pool: On the Evolution of Evolutionary Language," Studies in the History ofBiology, 1979, 3:241-285. And Adams summarizes the significance of the Russian strength in population biology in "Sergei Chetverikov, the Kortsov Institute, and the Evolutionary Synthesis," in The Evolutionaty Synthesis (ed. Mayr and Provine, cit. earlier in this section), pp. 242-278. Adams is currently working with Soviet scholars on a joint edition of the letters and papers of Theodosius Dobzhansky, the prominent Soviet geneticist who emigrated to the United States.

The related subject of eugenics occupies Loren R Graham in "Science and Values: The Eugenics Movement in Germany and Russia in the 1920Õs," The American Historical Review, 1977,

82(5):1133-1164, where he shows that interest in eugenics was not tied uniquely to right-wing political movements.

Before the advent of industrialization there was a strong school of ecology and conservation in the Soviet Union, one with important prerevolutionary roots. Douglas Weiner has explored this topic in number of articles, including "The Historical Origins of Soviet Environmentalism," Environmental Review, 1982, 6(2):42- 62; and "Community Ecology in Stalin's Russia: 'Socialist' and Bourgeois' Science," Isis, 1984, 75:684-696. Weiner has also written an important book analyzing the early history of Soviet conservation and identifying the roots of Lysenkoism: Models of Nature: Conservation and Ecology in the Soviet Union 1917-1935 (Bloomington: Indiana Univ. Press, 1987).

Biomedical Sciences: Physiology, Medicine, and Public Health

Russia has a particularly rich tradition in physiology and physiological psychology, as the names of I. M. Sechenov, V. M. Bekhterev, and Ivan Pavlov illustrate. David Joravsky's forthcoming Russian Psychology: A Critical History will treat this subject. Other sources are Daniel Todes, "Biological Psychology and the Tsarist Censor: The Dilemma of Scientific Development," Bulletin of the History of Medicine 1984, 58:529-544. B.P. Babkin, Pavlov (Chicago: Univ. Chicago Press, 1949); Y.P. Frolov, Pavlov and His School (London: K. Paul, Trench, Trubner & Co., 1937); Todes, "From Radicalism to Scientific Convention: Biological Psychology in Russia from Sechenov to Pavlov" (Ph.D;diss., Univ. Pennsylvania, 1981); and James E. Brett, "Materialist Philosophy in 19th-Century Russia: The Physiological Psychology of I. M. Sechenov" (Ph.D. diss. UCLA, 1975).

Two recent works examine doctors' organizations. The medical society founded in the name of Nikolai Pirogov, one of Russia's great anatomists, played an important role in late nineteenth- and early twentieth-century Russian medicine, and Nancy Mandellrer Frieden has examined its history in Russian Physicians in an Era of Reform and Revolution, 1856-1905 (Princeton, NJ.: Princeton Univ. Press, 1981). John P. Hutchtnson has written on professionallsm among Russian doctors in the nineteenth century in "Society, Corporation or Union? Russian Physicians and the Struggle for Professional Unity (1890- 1913)," Jahrbucher fur Geschichte Osteuropas, 1982, 30(1): 37- 53. Doctors themselves–or at least those who were women–are the focus of Jeanette E. Tuve, The First Russian Women Physicians (Newtonville, Mass.: Oriental Research Partners, 1984).

Interest among Western scholars in the history of Russian and Soviet public health has grown considerably in the last two decades. In 1986 Professor Susan Solomon of the University of Toronto organized a conference on the subject at which over a dozen papers were presented; much of this scholarship has yet to appear in print. One early book that examines public health in tsarist Russia is Roderick McGrew, Russia and the Cholera 1823-1832 (Madison: Univ. Wisconsin Press, 1965). Social historians are particularly interested in health-care delivery in nineteenth-century rural Russia; among recent works are Peter Krug, "The Debate over the Delivery of Health Care in Rural Russia: The Moscow Zemstvo, 1864-1878," Bulletin of the History of Medicine, 1976, 50:226-241; and two articles by Samuel Ramer: "Who Was the Russian Feldsher," Bulletin of the History ofMedicine, 1976, 50:213-235, and "Childbirth and Culture: Midwifery in the Nineteenth Century Russian Countryside," in The Family in Imperial Russia: New Lines of Historical Research, edited by David L. Ransel (Urbana: Univ. Illinois Press,1978), pp.218-235.

Early studies of Soviet medicine tended to be largely laudatory. See, for example, Henry E. Sigerist, Socialized Medicine in the Soviet Union (New York: Norton, 1937). A more critical and well-researched approach is found in Mark G. Field, Doctor and Patient in Soviet Russia (Cambridge, Mass.: Harvard Univ. Press, 1957); and in his Soviet Socialized Medicine: An Introduction (New York: Free Press, 1967). A book that includes considerable history is Gordon Hyde, The Soviet Health Service: An Historical and Comparative Study (London: Lawrence & Wishart, 1974). A good historical study of early Soviet public health is Christopher Davis, "Economic Problems of the Soviet Health Service: 1917-1930," Soviet Studies, 1983, 35(3):343-361.

Two other medical topics are covered in Julie V. Brown, "The Professionalization of Russian Psychiatry, 1857-1911" (Ph.D. diss., Univ. Pennsylvania, 1981), which looks at the history of Russian psychiatry from a sociological viewpoint; and John F. Hutchinson, "Tsarist Russia and the Bacteriological Revolution," Joumal of the History of Medicine and Allied Sciences 1985, 40(4):420-439, on intellectual, professional, and political resistance to and acceptance of bacteriology up to the 1905 Revolution.

Chemistry

Chemistry has a strong tradition in Russia, dating back to the first significant Russian scientist, Mikhail Lomonosov, continuing through A. M. Butlerov and D. I. Mendeleev in the nineteenth century, and persisting into the Soviet period, when N.N. Semenov won the Nobel Prize for his work on the kinetics of chemical reactions. This history, like that of much of Russian science, is poorly covered in the English-language Literature.

A well-known biography of Lomonosov is B.N. Menshutkin's Russia's Lomonosov, Chemist, Courtier, Physicist, Poet (Princeton, N.J.: Princeton Univ. Press, 1952). Unfortunately, Menshutkin's biography contains serious errors, such as the contention that Lomonosov did not believe in phlogiston. A Soviet biography of Lomonosov has recently been translated into English: Galina E. Pavlova and Aleksandr S. Fedorov, Mikhail Vasil'evich Lomonosov: His Life arul Work translated by Arthur Aksenov (Moscow: Mir Publishers, 1984). Another source is a collection edited by Henry M. Leicester, Mikhail Vasil'evich Lomonosov and the Corpuscular Theory (Cambridge, Mass.: Harvard Univ. Press, 1970). But despite the numerous publicaions about Lomonosov, especially in Russian, a critical evaluation of his place in the history of science has not yet been written.

Chemistry was established as a profession in Russia by the mid-nineteenth century. This development is analyzed in a valuable dissertation written in 1988 in the department at Columbia University by Nathan Marc Brooks entitled "The Formation of a Community of Chemists in 1700-1870." Chemistry was particularly strong at Kazan University, where A. M. Butlerov worked. Relevant sources on chemistry at Kazan and on Butlerov, one of the founders of structural chemistry, are S. N. Vinogradov, "Chemistry at Kazan University in the Nineteenth Century: A Case History of Intellectual Lineage," Isis, 1965, 56:168-173; and Henry M. Leicester, ÒAlexander Mlkhailovich Butlerov," Journal of Chemical Education, 1940, 17 (May): 208-209. On the controversial contributions of August Kekulé and Butlerov to the origins of structural chemistry, a useful article is Alan J. RockeÕs ÒKekulé Butlerov and the Historiography of the Theory of Chemical Structure," The British Joumal for the History of Science, 1981, 14(46):27-55.

No adequate biography of the great chemist Dmitrii Ivanovich Mendeleev exists in any language, not even Russian. Indeed, many of the existing treatments of Mendeleev are filled with errors, such as the often-repeated assertion that the reason he had a substitute read the most important paper of his career, the one on the "table of the elements," to the Russian Chemical Society was that he was sick; he " actually away from St. Petersburg on a consulting trip. On the positive side, the Soviet historian and philosopher B. M. Kedrov wrote an excellent description of the discovery of the table of the elements entitled The Day of One Great Discovery (Moscow: Nauka, 1958). Unfortunately, this book has not been translated into English, but it is summarized in Kedrov's article on Mendeleev in the Dictionary of Scientific Biography. Another useful source is Bernadette Bensaude-Vincent, "Mendeleev's Periodic System of Chemical Elements," British Journal of the History of Science, 1986, 19:3-17. For an emphasis on the effect that writing a textbook had on Mendeleev at the time he was developing the periodic table see Loren R. Graham, "Textbook Writing and Scientific Creativity: The Case of Mendeleev," National Forum Winter 1983, pp. 22-23. Two Ph.D. dissertations on Mendeleev emphasizing his social and political roles are Beverly Almgren, "Mendeleev: The Third Service, 1834-1882" (Brown Univ., 1968); and Francis Stackenwalt, "The Thought and Work of Dmitrii Ivanovich Mendeleev on the Industrialization of Russia, 1867-1907" (Univ. Illinois, 1976).

One reason that no adequate biography of Mendeleev has yet been written is that he was as active in politics and social issues as he was in chemistry. The future biographer faces a mountain of archival material, most of it collected in the Mendeleev Museum in Leningrad. Under Count Sergei Witte, minister of finance in the last decade of the nineteenth century, Mendeleev served as head of the Bureau of Weights and Measures, a position that was tantamount to being science adviser to the tsar's government. Mendeleev was never satisfied with government policies on economic development and was involved in many disputes. Part of this story can be found in Alexander Vucinich, "Mendeleev's Views on Science and Society," Isis 1967, 58:242-251.

A third chemist of this generation is better known as a composer of symphonies and opera, but Aleksandr Borodin made his living as a professor of chemistry at the St. Petersburg Academy of Medicine and Surgery. He roomed with Mendeleev when both were doing postgraduate study in Europe, and he and Butlerov wrote a biography of the organic chemist Nikolai Nikolaevich Zinin (who trained under Justus Liebig). A helpful, but far from complete biography is Nikolai I. Figurovskii and Yurii I. Solov'ev's Aleksandr Porfir'evich Borodin: A Chemist's Biography, translated by Charlene Steinberg and George Kauffman (New York: Springer Verlag, 1988). [See also George Sarton, "Borodin, 1833-87," Osiris 1939, 7:224-251.–Eds.] A memoir by an important Soviet chemist who emigrated to the United States, V.N. Ipatieff is Life of a Chemist (Stanford, Calif.: Stanford Univ. Press, 1946).

Soviet historians have written a great deal on the history of chemistry, but as with other topics in this teaching guide, I will not attempt to describe the Russian- language literature. For an overview of the evolution of Soviet interpretations of the history of chemistry readers can, however, turn to Yakov M. Rabkin, "Trends and Forces in the Soviet History of Chemistry," Isis, 1976, 67:257-273.

Physics

The Soviet Union has traditionally been very strong in the theoretical foundations of physics. In general relativity theory, A. A. Fridman (Friedmann) produced a brilliant mathematical approach

that showed that Einstein was wrong to think that his equations of 1915 could lead only to a static universe, an error that Einstein graciously admitted after seeing Fridman's work.

Beginning in the early 1930s Vladimir Fock, Lev Landau, and Igor Tamm made contributions to quantum field theory that attracted attention from leading physicists around the world. At about the same time, P. A. Cherenkov began his work under the Supervision of S. I. Vavilov on the action of radiation on liquids. This led to his discovery of the Cherenkov effect, for which in 1958 he received the Nobel Prize (along With I. M. Frank and Tamm). Ia. I. Frenkef' was well known in the 1930s and 1940s for his work on electrodynamics and especially for his two-volume text on the subject. At the same time L.A. Artsimovich, I.Ia. Pomeranchuk, and D.D. Ivanenko were doing important work on quantum electrodynamics. The textbooks on theoretical physics by Lev Landau and E. M. Lifshits came to be known to physicists everywhere. Also in the 1930s Landau and B. I. Davydov established a strong tradition in plasma physics that has continued to the present day. In later years some of the most intluential workers in this field have been V. L. Ginzburg, R. Z. Sagdeev, E. P. Velikhov, L.A. Artsimovich, M.A. Leontovich, A.D. Sakharov, and I. E. Tamm. Sakharov (later famous in the West for his protests against Soviet violations of civil rights) and Tamm suggested the Tokamak toroidal model for controlled fusion, which was widely accepted internationally as a basis for continuing experimentation.

The founder of Soviet work in solid state physics was A. F. Ioffe, a major figure in the history of Soviet science. In 1918 Ioffe established the Leningrad Physico-Technical Institute, which became the cradle of Soviet physics. In a forthcoming history of this institute Paul Josephson describes the 1920s as a "flowering of Soviet physics," a time when a group of talented young Soviet physicists flourished under Ioffe's tutelage. Among the members of Ioffe's group were A. P. Aleksandrov (future president of the Academy of Sciences), A. I. Alikhanov, L. A. Artsimovich, P. L. Kapitsa (Nobel laureate), I. KKikoin, V. N. Kondrat'ev, B. P. Konstantinovich, I.V. Kurchatov (later leader of the Soviet atomic weapon project), L.D. Landau (Nobel laureate), P. I. Lukirskii, N. N. Semenov (Nobel laureate), D. V. Skobectsyn, and Ia. I. Frenkel'.

Another bright page in the recent history of Soviet physics has been quantum electronics, where new methods have been found for the generation and intensification of electromagnetic waves. In 1964 the Soviet physicists N. G. Basov and A. M. Prokhorov, together with the American physicist C. H. Townes, received the Nobel Prize for research leading to the development of lasers and masers.

Unfortunately, there is very little scholarly work in English on the history of Soviet physics. Good articles on the early history are Paul Josephson, "The Early Years of Soviet Nuclear Physics," Bulletin of the Atomic Scientists 1987, 43(10):36-39; Josephson, "Physics, Stalinist Politics of Science and Cultural Revolution," Soviet Studies, 1988, 40(2):245-265 and Josephson, "Physics and Soviet-Western Relations in the 1920s and 1930s," Physics Today, 1988, 41(9):54-61. Peter Kapitsa, once the Soviet Union's best-known physicist because of his capture by Stalin while on home leave from England in 1934, has been the subject of several popular biographies, but no one has made use of the Kapitsa family archives. Lawrence Badash has included some of the correspondence between Kapitsa and his wife, Anna, in his Kapitza Rutherford and the Kremlin (New Haven, Conn.: Yale Univ. Press, 1985). Kapitsa's collection of articles Experiment, Theory, Practice has been published in English (DordrechtlBoston: D. Reidel, 1980). Also useful is the collection Peter Kapitsa on Life and Science: Addresses and Essays, edited and translated by Albert Parry (New York: Macmillan, 1968).

An aspect of Soviet physics that has attracted some attention in the West has been atomic weapons and atomic energy. See David Holloway's Entering the Nuclear Arms Race: The Soviet Decision to Build the Atomic Bomb, 1939-1945 (Working Paper 9, International Security Studies Pro- gram) (Washington, D.C.: The Wilson Center, 1979); and his book The Soviet Union and the Arms Race (New Haven, Conn.: Yale Univ. Press, 1985). An old book still of some value is Amold Kramish's Atomic Energy in the Soviet Union (Stanford, Calif.: Stanford Univ. Press, 1959). I. Golovin's Soviet biography of Igor Kurchatov, the head of the Soviet atomic bomb project, has been translated into English by William H. Dougherty: I.V. Kurchatov: A Socialist-Realist Biography of the Soviet Nuclear Scientist (Bloomington, Ind.: Selbstverlag Press, 1968). After the accident at the Chernobyl nuclear power reactor in the spring of 1986, many Westerners became interested in Soviet policies toward atomic energy. Sources on this topic include Paul Josephson, "The Historical Roots of the Chernobyl Disaster,Ó Soviet Union/Union Sovietique, 1986, 13(3):275-299. David R. Marples, Chernobyl and Nuclear Power in the USSR (New York: Macmillan, 1987); and Marples, The Social Impact of the Chemobyl Disaster (New York: St. Martin's Press, 1988).

Andrei Sakharov is currently the most famous of the Soviet Union's physicists. Although no complete biography of him exists, there are a number of collections of his writings or of writings about him, such as Sakharov Speaks, edited by Harrison E. Salisbury (New York: Vintage Books, 1974); On Sakharov, edited by Alexander Babyonyshev and translated by Guy Daniels (New York: Knopf, 1982); and Sakharov's My Country and the World translated by Guy Daniels (New York: Vintage Books, 1975).

An interesting attempt to compare Soviet and Western research in high-energy physics is John Irvine and Ben R. Martin, "Basic Research in the East and West: A Comparison of the Scientific Performance of High-Energy Physics Accelerators," Social Studies of Science, 1985, 5(2): 293-341.

Astronomy

Astronomy is a field in which Russia achieved eminence long before the Revolution of 1917. The Pulkovo Observatory near St. Petersburg was a center of outstanding work throughout the nineteenth century. Its founder, the Baltic German F. G. W. Struve, became famous for his measurements of stellar parallax and his accurate observations of double stars. Struve established not only a tradition of outstanding astronomical work but also a family line of astronomers that lasted for four generations; his grandson Otto Struve, a well-known American astrophysicist, promoted international knowledge of Soviet astronomy. See, for example, Otto Struve, "The Pulkovo Observatory (1839- 1941)," Sky and Telescope, 1941, 1(4):3-14, 19.

Soviet astrophysics has been particularly strong in recent years. The groups of R. Z. Sagdeev, Ia.B. ZelÕdovich, and Iu.S. Shklovskii at the Institute of Space Research, V. L. Ginzburg at the Lebedev Institute, and I. M. Khalatnikov at the Landau Institute of Theoretical Physics have attracted international attention from physicists and astronomers, but this work is too recent to be featured in the works of historians.

The only American currently working on the history of Soviet astronomy is Robert McCutcheon, who is studying the effects of the purges of the 1930s on astronomy.

Space Exploration

A Russian pioneer in space research, somewhat similar to Robert Goddard in the United States, was Konstantin Tsiolkovskii (1857-1935), who is the subject of an uncritical Soviet biography in English: A.A. Kosmodemianskii, Konstantin Tsiolkovsky: His Life and Work (Moscow: Foreign Languages Publishing House, 1956). Tsiolkovskii's collected works were translated into English by NASA: The Collected Works of K. E. Tsiolkovskiy, edited by B. N. Iur'ev and A.A. Blagonravov (Moscow, 1951-1959 NASA TT F-236, 237, 238, Washington, D.C., 1965). An interpretation of the image of Tsiolkovskii in Soviet literature is Rita DeDomenico's "The Official Image of Konstantin Tsiolkovsky in the Soviet Union, 1959-1970" (senior thesis, Harvard Univ., 1986).

Many histories of the Soviet space program suffer from being anecdotal and written for a popular audience. Two such works are James Oberg, Red Star in Orbit (New York: Random House, 1981); and Leonid Vladimirov, The Russian Space Bluff: The Inside Story of the Soviet Drive to the Moon (New York: Dial Press, 1973). An exception is a Pulitzer Prize-winning work by a qualified historian comparing the Soviet and American space programs: Walter McDougall, The Heavens and the Earth (New York: Basic Books, 1985). However, McDougall's work is much stronger in its use of English sources than of Russian ones.

Geology

Although the Soviet Union currently has more geologists than any other country in the world, very little exists in English on the history of Russian and Soviet geology. One notewonhy work is the biography of Academician Vladimir Vernadsky by Kendall Bailes, entitled Science and Russian Culture in an Age of Revolution: Vemadsky and His Scientific School 1863-1945 (Bloomington: Indiana Univ. Press, 1989).

The Soviet Union was slow in adapting to the revolution in geology brought about by plate tectonics. Robert M. Wood gives some of the reasons for this lag in his "Geology vs. Dogma: The Russian Rift," The New Scientist, 12 June 1980, pp. 234- 237.

Technology

Relatively little has been written in the West on the history of technology in Russia and the Soviet Union, but interest in the subject is beginning to grow. A study of the early metallurgy industry is Arcadius Kahan, "Entrepreneurship in the Early Development of Iron Manufacturing in Russia," Economic Development and Cultural Change, 1962, 10:395-412. The casting of bells was an important technology related to the casting of cannons; its history in Russia is explored in Edward V. Williams, The Bells of Russia: History and Technology (Princeton, N.J.: Princeton Univ. Press, 1985). William Blackwell provides an introduction to Russian industrialization in The Beginnings of Russian Industrialization 1800-1860 (Princeton, NJ.: Princeton Univ. Press, 1968). The early history of railroads in Russia is explored in Richard M. Haywood, The Beginnings of Railway Development in Russia and the Reign of Nicholas I; 1835-1842 (Durham, N.C.: Duke Univ. Press, 1969). Jonathan Coopersmith is working on a study of the history of electrification in prerevolutionary Russia and has already published "The Role of the Military in the Electrification of Russia, 1870-1890," in Science, Technology and the Military, edited by E. Mendelsohn, M. R. Smith, and P. Weingart (Dordrecht/Boston: D. Reidel,1988), pp. 291-305.

Engineering has also proved a fruitful area of research. Harley Baiter has written a valuable study of prerevolutionary technical education: “Educating Engineers: Economic Politics and Technical Training in Tsarist Russia” (Ph.D. diss., Univ. Pennsylvania, 1980). Baiter is currently preparing a volume on engineers in Russian and Soviet culture. An outstanding history of the role of technology and engineers in the political and social development of the Soviet Union is Kendall Bailes, Technology and Society under Lenin and Stalin: Origins of the Soviet Technical Intelligentsia, 1917-41 (Princeton, NJ.: Princeton Univ. Press, 1978), a study for which Bailes received a prize for scholarly excellence from the American Historical Association. Studies of Taylorism in Soviet Russia include Bailes, “Alexei Gastev and the Soviet Controversy over Taylorism, 1918-1924,” Soviet Studies 1977, 29(3):373-394 and Zenovia Sochor, “Soviet Taylorism Revisited,” Soviet Studies 1981, 33(2):246- 264. Another useful work is Nicholas Lampert, The Technical Intelligentsia and the Soviet State (New York: Macmillan, 1979).

Several works, particularly in the area of political science, treat the history of technology less directly. Bruce Parrott is a political scientist, but his book Politics and Technology in the Soviet Union (Cambridge, Mass.: MIT Press, 1983) provides much historical material. Additional themes are treated in Robert Lewis, Science and Industrialization in the USSR (New York: Macmillan, 1979); Lewis A. Siegelbaum, Stakhanovism and the Politics of Productivity in the USSR 1935-1941 (Cambridge: Cambridge Univ. Press, 1988); and Hiroaki Kuromiya, Stalin’s Industrial Revolution (Cambridge: Cambridge Univ. Press, 1988).

The influence of Western technology is the focus of two works. A massive work whose author is unwilling to grant independent industrial achievements to the Soviet Union is Antony Sutton, Western Technology and Soviet Economic Development; 3 vols. (Stanford, Calif.: Stanford Univ. Press, 1968-1973). Mark Kuchment has written an article detailing the birth of the Soviet microelectronics industry and the role played in it by two American engineers: “Active Technology Transfer and the Development of Soviet Microelectronics,” in Selling the Rope to Hang Capitalism? edited by Charles Ferry and Robert Pfaltz- graff, Jr. (Washington, D.C.: Pergamon-B’assey, 1987), pp. 60-69.

Policy Studies

Because of the rivalry between the United States and the Soviet Union in international relations, a competition necessarily involving science and technology, a large literature exists on science and technology policy in the Soviet Union. Few of these works are of interest to historians, but I will mention some that might be useful. Loren Graham takes a historical look at Soviet science policy in “The Development of Science Policy in the Soviet Union,” in Science Policies of Industrial Nations, edited by T. Dixon Long and Christopher Wright (New York: Praeger, 1975), pp. 12-58. An updated version includes Gorbachev’s reforms in science: see Graham, ÒScience and Technology Trends in the Soviet Union,” in Framework for Interaction: Technical Structures in Selected Countries outside the European Community, edited by Herbert Fusfeld (Troy, N.Y.: Rensselaer Polytechnic Institute, 1987), pp. II-D-1 to II-D-44. Harley Baiter has also written on science under Gorbachev: “Is Less More! Soviet Science in the Gorbachev Era,” Issues in Science and Technology, 1985, 1(4):29-46. For a critical view of Soviet science written by a prominent researcher and administrator in the USSR, see Roald Sagdeev, “Science and Perestroika: A Long Way to Go,” Issues in Science and Technology, 1988, 4(4):48-52.

Paul Josephson discusses early Soviet science policy in "Science Policy in the Soviet Union, 1917–1927," Minerva, 1988, 26(3):342-369. Soviet science policy in the period 1945-1975 is treated in Mark Adams, "Biology After Stalin: A Case Study," Survey, No. 102, Winter 1977-1978, pp. 53-80. Works that describe the main institutions making science policy in the Soviet Union include E. Zaleski et al, Science Policy in the USSR (Paris: OECD, 1969); Paul Cocks, Science Policy USA-USSR, Vol. II (Washington, D.C.: National Science Foundation, 1980); and John Thomas and Ursula Kruse-Vaucienne's edited volume Soviet Science and Technology (Washington, D.C.: George Washington Univ. Press, 1976).

An excellent analysis of the strengths and weaknesses of fundamental science in the USSR is Thane Gustafson, "Why Doesn't Soviet Science Do Better Than It Does?" in The Social Context of Soviet Science (ed. Lubrano and Solomon; see Section I), pp. 31-68. This volume also contains articles by Bruce Parrott (on the organization of Soviet applied research), Linda Lubrano (on Soviet scientific collectives), Kendall Bailes (on the social backgrounds of technical specialists), and Loren Graham (on genetic engineering).

Important topics of discussion among Soviet science policy specialists have been the place of science in Marxist ideology and the role of "STR" (the "scientific-technical revolution") in Soviet society. Helpful sources on these topics include Paul Josephson, "Science and Ideology in the Soviet Union: The Transformation of Science into a Direct Productive Force," Soviet Union 1981, 8(2):159-185; Julian Cooper, "The Scientific and Technical Revolution in Soviet Theory," in Technology and Communist Culture, edited by Frederic J. Fleron (New York: Praeger, 1977); Robert Miller, "The Scientific-Technical Revolution and the Soviet Administrative Battle," in The Dynamics of Soviet Politics edited by Paul Cocks et al (Cambridge, Mass.: Harvard Univ. Press, 1976), pp. 137-155 and Erik Hoffmann, "Soviet Views of the Scientific-Technological Revolution," World Politics July 1978, pp. 615-644.

An interesting article on the growth of scientific personnel in the USSR, portraying the Soviet overtaking of the United States in the number of research workers, is Louvan Nolting and Murray Feshbach's "R and D Employment in the USSR" Science 1 Feb. 1980, 207:493-503. Nolting has also published a series of reports (Foreign Economic Reports, Department of Commerce) on the structure and organization of Soviet science and technology.

A recent and valuable analysis of the political role of Soviet science by Stephen Fortescue is The Communist Party and Soviet Science (London: Macmillan, 1987). Another book treating some of the same issues is Peter Kneen's Soviet Scientists and the State (Albany: SUNY Press, 1984). Works written by emigres who previously worked in the Soviet science establishment provide special insights; these include Mark Azbel, Refusenik: Trapped in the Soviet Union (Boston: Houghton Mifflin, 1981); Mark Popovsky, Manipulated Science (Garden City, N.Y.: Doubleday, 1979); and Vladimir Kresin, "Soviet Science in Practice: An Insider's View," in The Soviet Union Today, edited by James Cracraft (Chicago: Bulletin of Atomic Scientists, 1983).

Three works treating Soviet industrial research from economic and political standpoints are Joseph Berliner, The Innovation Decision in Soviet Industry (Cambridge, Mass.: Harvard Univ. Press, 1976); Erik Hoffmann and Robbin Laird, Technocratic Socialism: The Soviet Union in the Advanced Industrial Era (Durham, N.C.: Duke Univ. Press, 1985); and Raymond Hutchings, Soviet Science: Technology and Design Interaction and Convergence (London: Oxford Univ. Press, 1976).

A topic of particular interest to American scholars who may wish to do research in the Soviet Union, no matter what the field, is the history of scholarly exchanges between the United States and the USSR. The most thoughtful analysis of the subject is by Linda Lubrano, "National and International Politics in USA-USSR Scientific Cooperation," Social Studies of Science 1981, 11:451-480. Also see Review of USA-USSR Interacademy Exchanges and Relations, Report of the National Academy of Sciences (Washington, D.C., 1977); and Yale Richmond, U.S.-Soviet Cultural Ex- changes 1958-1986: Who Wins? (Boulder, Colo.: Westview Press, 1987).

CONCLUSION

From the above pages it is clear that the history of Russian and Soviet science and technology is now a developing field in English-speaking countries. However, English language sources alone are not adequate for serious research on this subject. For readers of Russian, I have available a much longer bibliography (not annotated, but listed in categories), and would be happy to mail it to those who ask for it; write Loren Graham, Program on Science, Technology and Society, Room E51-128, MIT, Cambridge, MA 02139. Russian-language films on the history of Russian and Soviet science can be purchased from Alexandre K. Surikov, President, All-Union Corporation "Sovinfilm," 20 Skatertny Per., Moscow 121069, USSR.