FROM NEWSPEAK TO CYBERSPEAK

A HISTORY OF SOVIET CYBERNETICS

SLAVA GEROVITCH

From Newspeak to Cyberspeak

This Page Intentionally Left Blank

From Newspeak to Cyberspeak

A History of Soviet Cybernetics

Slava Gerovitch

The MIT Press
Cambridge, Massachusetts
London, England

Set in Sabon by The MIT Press.
Printed and bound in the United States of America.

Library of Congress Cataloging-in-Publication Data

Gerovitch, Slava.
From newspeak to cyberspeak : a history of Soviet cybernetics / Slava Gerovitch.
p. cm.
Includes bibliographical references and index.
ISBN 0-262-07232-7 (hard cover : alk. paper)
1. Cybernetics—Soviet Union—History. I. Title.
Q305 .G47 2002
003'.5'0947—dc21 2001056241

for my mother, Raisa Sklyar

This Page Intentionally Left Blank

Contents

Preface and Acknowledgements xi

Introduction: Soviet Science and Politics through the Prism of Language 1

1 The Cold War in Code Words: The Newspeak of Soviet Science 11

Balancing Military and Ideological Priorities for Cold War Science 14

Shifting Boundaries between Knowledge and Ideology 18

Newspeak: The Fundamentals 21

Scientific Newspeak 26

"Formalism" as a Floating Signifier 31

From Formulas to "Formalism" in Mathematics 33

From Literary Form to "Formalism" in Linguistics 37

The Specter of "Idealism" in Physiology 42

2 Cyberspeak: A Universal Language for Men and Machines 51

Norbert Wiener and Andrei Kolmogorov: Two Mathematicians Tackle Biology 56

Control via Feedback: The Body as a Servomechanism 61

The Order of Life: The Organism as an Entropy-Reducing Machine 64

Human Communication as an Engineering Problem: Man as an "Information Source" 67

The Computer and the Mind as Universal Logical Machines 72

The Logic of the Brain: The Nervous System as a Turing Machine 75

The Computer as a Brain and the Brain as a Computer 79

The Making of Cyberspeak and the Emergence of Cybernetics 83

Cyberspeak Becomes Universal 89
The Cybernetics Bandwagon 96

3 "Normal Pseudo-Science" 103
Cybernetic Ideas in a Soviet Context: Pro and Contra 105
"Russian Scandal" at the Root of Cybernetics 113
Postwar Ideological Campaigns as Rituals 115
The Cybernetics "Scandal" 118
Serial Reproduction of Criticism 126
Computers as "Mathematical Machines" of the Cold War 131
The Military Definition of Computing: Technology without Ideology 142
Soviet Computers: A State Secret or a "Display Technology"? 150

4 Cybernetics in Rebellion 153
Soviet Science in Search of a New Language 153
Soviet Computers: Declassified and Deified 155
The Computer as a Paragon of Objectivity 161
Soviet Philosophy between Scylla and Charybdis 163
The Newspeak Defense of Cybernetics 166
The Military Defense of Cybernetics 173
Cyberspeak Challenges Newspeak 179
Cybernetics and Genetics: A Common Cause 183
Cybernetics Challenges Soviet Philosophy 188
The Legitimation of Cybernetics 193

5 The "Cybernetization" of Soviet Science 199
Cybernetics as a "Trading Zone" 200
The Council on Cybernetics as an Institutional "Umbrella" 204
Biological Cybernetics: Genes as "Units of Hereditary Information" 211
The Mathematical "Axioms of Life" 214
Physiological Cybernetics: The Brain as a Subject of Technology 218
"Man Is the Most Perfect of All Known Cybernetic Machines . . ." 224
Cybernetic Linguistics: Making the Study of Language an "Exact Science" 227
From Machine Translation to Linguistic Theory 232

The Fate of the Institute of Cybernetics 241
"What Is Cybernetics?" 246

6 Cybernetics in the Service of Communism 253
"Cybernetics in the Service of Communism" 253
The "Dialectical Materialization" of Cybernetics 257
Cybernetics in Fashion 260
From "Military Cybernetics" to "Economic Cybernetics" 264
"Optimal Decision-Making on a National Scale": Aspirations and Constraints 268
"Optimal Planning": A Vehicle of Economic Reform or an Obstacle to It? 274
Cybernetics in the Service of the Establishment 279
CyberNewspeak: The "Scientific Management of Society" 285
The End of the Cybernetics Game 288

Conclusion Soviet Cybernetics: Prometheus or Proteus? 293
Cyberspeak as a Carnival Language 293
Cyberspeak as an Instrument of Freedom 296
Cyberspeak as a Universal Language of Capitalism and Communism 300

Notes 305
Index 361

This Page Intentionally Left Blank

Preface and Acknowledgements

The language of Soviet science always fascinated me. Working on my first course papers after coming from what then was the Soviet Union to the United States for graduate study in 1992, I quickly discovered that the dominant styles of academic discourse in the two countries were vastly different. While American academics preferred precise, unambiguous wording, Russians often valued more intricate and vague formulations open to multiple interpretations. Pondering the cultural roots of this phenomenon, I was particularly intrigued by the story of the Soviet cybernetics movement, which made a bold attempt to introduce "precise language" into Soviet science. In this book, I explore intellectual, social, and political tensions arising from the clash of different styles of academic discourse. Ironically, this book itself is an amalgam of different styles: I tried to make the narrative both strict and imaginative, both direct and subtle, both impartial and emotional. The story I am about to tell has many dimensions, and I tried both to make it comprehensible and to preserve its complexity.

From Newspeak to Cyberspeak began its life as a doctoral dissertation in the Program in Science, Technology, and Society at the Massachusetts Institute of Technology. After defending my first dissertation at the Russian Academy of Sciences in Moscow in early 1992, I could hardly imagine that a few years later I would write another one. When I was in Russia, my research focused on the United States; ironically, when I moved to the United States, I shifted this focus to Soviet science and technology. This book is the result of my geographical, cultural, professional, and linguistic transition into a new world. At the same time, this book is about the world I left: the country which since disappeared and the circle of Soviet intelligentsia which since dissipated into networks of post-Soviet intellectuals.

I still love that old world, but my feelings, like my thoughts and dreams, are now expressed in English.

My life changed after a fateful meeting with Loren Graham in Moscow in January of 1991, when he came to the Institute for the History of Natural Science and Technology to meet with young Russian historians. His great curiosity, vast erudition, and originality of thought have become my primary source of intellectual challenge and personal delight. As his research assistant for many years afterward, I benefited both from his material support and from his friendly advice. He encouraged me to come to the United States and did everything he could to ease my cultural shock. As my dissertation advisor, he trusted me to work in my own style, at my own speed, and never expected less than my best efforts. Finally, Loren himself has become for me a model of creativity and integrity in scholarship and in life.

It was my privilege to meet and work with many colleagues and friends, whose intellectual fire and hearty attitude made my work on this topic a pleasure. Members of my dissertation committee—Jed Buchwald, Tom Hughes, and Elizabeth Wood—sacrificed much time and effort trying to make my thoughts clearer for me. Jed not only allowed me to omit mathematical formulas from my text but even gave some advice on how to make the narrative more engaging. Tom posed pointed questions that set me on the right track. Elizabeth opened for me a whole new perspective on Soviet history and on "the Soviet language," making me reexamine many conventional assumptions. I am also profoundly grateful to many American and Russian colleagues and friends who read drafts of various dissertation and book chapters and journal articles and provided useful comments and criticisms: Pnina Abir-Am, Mikhail Arkadiev, David Mindell, Anne Fitzpatrick, Hugh Gusterson, David Hounshell, Paul Josephson, Lily Kay, Alexei Kojevnikov, Nikolai Krementsov, Miriam Levin, Andy Pickering, Silvan Schweber, Mark Solovey, John Staudenmaier, SJ, and Jerôme Segal. I also benefited from personal and electronic communication with Mark Adams, Mario Biagioli, Chris Bissell, David Bloor, Nathan Brooks, Carl Caldwell, Andrew Jenks, Yale Richmond, James Schwoch, Asif Siddiqi, and Douglas Weiner. I am especially indebted to the reviewers of my manuscript for the MIT Press—Paul Edwards, Peter Galison, and David Holloway—who not only refused anonymity but also actively helped me revise the manuscript by providing frank and detailed criticism and extremely valuable

suggestions. My special thanks to my editor, Larry Cohen, whose gentle support and guidance allowed me to survive the ordeal of major manuscript revisions.

This study greatly benefited from my interviews and correspondence with people who were personally involved in the Soviet cybernetics movement: the chemist Iurii Adler, the linguist Vladimir Alpatov, the philosopher Boris Biriukov, the mathematician Akiva Iaglom, the psychologist Mikhail Iaroshevskii, the mathematician Iakov Khurgin, the mathematician Ol'ga Kulagina, the chemist Elena Markova, the philologist Susanna Maschan, the linguist Igor' Mel'čuk, the mathematician Il'ia Muchnik, the mathematician Nikolai Nagornyi, the mathematician Vasilii Nalimov, the computer programmer Rimma Podlovchenko, the biologist Inga Poletaeva, the mathematician Gelii Povarov, the mathematician Iulii Shreider, the military analyst Oleg Sosiura, and the linguist Alexander Zholkovsky. I am especially grateful to the biologist Natal'ia Liapunova, who not only told an emotional and touching story of the life of her father, the late cybernetician Aleksei Liapunov, but also gave me the wonderful opportunity to examine the immensely rich archive of her father's personal papers.

My research would not have been possible without enormous help from the staff of the Russian Academy of Sciences Archive, the Russian State Archive of Literature and Art, the Russian State Archive of Contemporary History, the Russian State Archive of Socio-Political History, and the Central Archive of Social Movements of Moscow. Stanislaw Raczynski, Deputy Director of the Institute of Precise Mechanics and Computer Technology in Moscow, helped me access the archival papers of that institute. Elizabeth Andrews of the MIT Archives rendered assistance in my study of the papers of Norbert Wiener and Roman Jakobson.

My colleagues at the Institute for the History of Natural Science and Technology in Moscow welcomed me back every summer when I returned to Moscow for archival research, and they provided for me an enjoyable and stimulating intellectual milieu. Alexander Pechenkin and Kirill Rossiianov helped with collecting copies of archival and printed materials.

Special thanks to the Program in Science, Technology, and Society at MIT and to the Dibner Institute for the History of Science and Technology for providing teaching and research assistantships and fellowships that sustained me through the years of my doctoral and postdoctoral study. I also benefited from a short-term grant from the International Research &

Exchanges Board, with funds provided by the US Department of State (Title VIII Program) and the National Endowment for the Humanities. None of these organizations is responsible for the views expressed.

The most difficult problem of my cultural adaptation in the United States was to find my voice in English. My copy editor, Paul Bethge, tried patiently to harness my unruly metaphors and to find seriousness in my irony. I cannot thank him enough for his companionship in the search for an approximate English expression of inexplicable Russian thoughts.

Finally, my parents, Raisa Sklyar and Aleksandr Gerovitch, my brother Simon, and my wife Maya offered me the kind of love, respect, and support that nobody else could give. Their belief in me held me up at difficult times. Thanks to them, in the last several years I found home in a new land and experienced some of the happiest moments in my life.

Introduction
Soviet Science and Politics through the Prism of Language

Communist society had indeed engendered a new universal language, detached from nature and subordinate to pure thought. . . . All situations, things, or men, can be reduced to a principle which transcends them.

—Françoise Thom, *Newspeak: The Language of Soviet Communism*[1]

Cyberneticians argued that we were now at an historical conjuncture where machines were becoming sufficiently complex and the relationship between people and machines sufficiently intense that a new language was needed to span both: the language of cybernetics.

—Geoffrey Bowker, "How to Be Universal: Some Cybernetic Strategies"[2]

The history of Soviet cybernetics is a story of rebellion and conformity, of enchantment and disappointment, and of fascination with a new revolutionary language and frustration when this language was appropriated by the establishment. Soviet cybernetics was not simply an intellectual trend; it was a social movement for radical reform in science and in society in general. Cyberneticians came to believe in the possibility of a universal method of problem solving if only problems could be formulated in the right language. They viewed computer simulation as this universal method, and the language of cybernetics as a language of objectivity and truth. Soviet cybernetics challenged the existing order of things not only in the conceptual foundations of science but also in economics and politics.

Like cybernetics itself, which transcended the boundaries of any particular discipline, this book deals with social and political as well as intellectual developments in Soviet science from the late 1940s through the early 1970s. It looks at these developments through the prism of language because the aspiration to create a precise, universal scientific language was central to the cybernetic project and played a prominent role in the origins, the rise, and the fall of Soviet cybernetics.

Cybernetics is an unusual historical phenomenon. It is not a traditional scientific discipline, a specific engineering technique, or a philosophical doctrine, although it combines many elements of science, engineering, and philosophy. As presented in Norbert Wiener's classic 1948 book *Cybernetics, or Control and Communication in the Animal and the Machine*, cybernetics comprises an assortment of analogies between humans and self-regulating machines: human behavior is compared to the operation of a servomechanism; human communication is likened to the transmission of signals over telephone lines; the human brain is compared to computer hardware and the human mind to software; order is identified with life, certainty, and information; disorder is linked to death, uncertainty, and entropy.[3] Cyberneticians view control as a form of communication, and communication as a form of control: both are characterized by purposeful action based on information exchange via feedback loops. Cybernetics unifies diverse mathematical models, explanatory frameworks, and appealing metaphors from various disciplines by means of a common language that I call *cyberspeak*. This language combines concepts from physiology (*homeostasis* and *reflex*), psychology (*behavior* and *goal*), control engineering (*control* and *feedback*), thermodynamics (*entropy* and *order*), and communication engineering (*information*, *signal*, and *noise*) and generalizes each of them to be equally applicable to living organisms, to self-regulating machines, and to human society.

In the West, cybernetic ideas have elicited a wide range of responses. Some view cybernetics as an embodiment of military patterns of command and control; others see it as an expression of liberal yearning for freedom of communication and grassroots participatory democracy. Some trace the origins of cybernetic ideas to wartime military projects in fire control and cryptology; others point to prewar traditions in control and communication engineering. Some portray cyberneticians' universalistic aspirations as a grant-generating ploy; others hail the cultural shift resulting from cybernetics' erasure of boundaries between organism and machine, between animate and inanimate, between mind and body, and between nature and culture.[4]

In the Soviet Union, cyberspeak acquired an entirely new set of connotations. In his memoirs, the prominent Soviet dissident Vladimir Bukovskii has chosen the following image to highlight the fundamental incompatibility between the rational thinking of some Soviet dissident scientists and the irrationality of the Soviet regime:

> Just imagine for a moment that for some reason the KGB decides to arrest a computer. On the one hand, it is impossible to intimidate or trap a computer, to entice it to a compromise, to force a false confession, or even make it tell a lie, however small. On the other hand, a computer would not be able to understand the ambiguous language of inquiry, the language of the Soviet law. Its logical circuits would either give a binary yes-or-no answer, or—for an extended reply—would produce a long perforated tape with endless zeroes and ones. What will they do with it? Attach to a dossier?[5]

Here the logical rigor and mathematical precision of computer algorithms and calculations is opposed to the ideology-laden language of Soviet slogan-like public statements, which cannot be questioned or verified but are assumed to be true a priori. Since the publication of George Orwell's *Nineteen Eighty-Four*, this ideological language has often been referred to as *newspeak*.

Although Soviet ideological texts often appeared ambiguous and illogical, newspeak did have its own patterns and rules, which some observers, ironically, compared to computer algorithms. The cultural theorist Mikhail Epstein argued that "Soviet Marxist ideological language is by its very nature artificial; it would be possible to outline its structure using abstract formulas" and that "with specific formulas of functions and markers, a computer would be capable of composing Soviet ideological texts."[6] William Griffith similarly suggested that the deciphering of Soviet "esoteric communications" could perhaps be "better and more easily done by an electronic computer."[7] Then was there a fundamental conflict or an inherent concord between newspeak and cyberspeak?

This book focuses on the historical encounter between the language of cybernetics and the Soviet ideological language. It is a history of Soviet cybernetics as a discourse—an ensemble of practices of producing, articulating, communicating, and manipulating knowledge, a language phenomenon as much as a mathematical theory or an engineering technique. The analysis of cybernetics as a discursive phenomenon brings to the fore the rich political, ideological, and cultural connotations of the cybernetic notions of control and communication that reverberated in Soviet cybernetic texts. I argue, in fact, that cyberspeak was as much an ideological language as it was a language of science.

No other field of science or engineering underwent such frequent and profound changes of attitude in the Soviet Union as cybernetics. The historian Paul Josephson has recently called it "unimaginable that a culture so fascinated with the potential of science to build communism, a culture whose achievements in the 1950s included the hydrogen bomb, nuclear power, tokamaks, and Sputnik, could dismiss the promise of cybernetics."[8] As with many other unimaginable things, however, this was precisely what happened at first in the Soviet Union. In 1954 the *Short Philosophical Dictionary* defined cybernetics as a "reactionary pseudo-science" and "an ideological weapon of imperialist reaction."[9] By the late 1950s, cybernetics was recognized as an innocent victim of political oppression and "rehabilitated" along with some of the political prisoners of the Stalinist regime. Soviet cybernetics emerged as a movement for radical reform of the Stalinist system of science. It gained wide popularity, and in the early 1960s it was written into a new Party Program and hailed as a "science in the service of communism." By the late 1960s, however, cybernetics began to lose intellectual content and turn into a fashionable trend. In the 1970s, disillusioned former cybernetics enthusiasts liked to tell a bitter joke: "They told us before that cybernetics was a reactionary pseudo-science. Now we are firmly convinced that it is just the opposite: cybernetics is not reactionary, not pseudo-, and not a science."[10] In the 1990s, the cybernetics boom was blamed for numerous shortcomings of Soviet science. "This doctrine, which called itself a science of control, chained the technological élan of a great nation," wrote one commentator in a Russian on-line magazine. "Domestic science wasted immeasurable time and effort on the chimera of cybernetics, while the field of computer technology was deprived of full-scale funding."[11]

The fluctuating attitudes toward cybernetics represented something larger than mere rejection or acceptance of a particular scientific approach: they reflected profound changes in scientific language and research methodology across a wide range of disciplines, in the system of power relations within the scientific community, and in the political role of scientists and engineers in Soviet society. Through the lens of cybernetics, one can observe some salient features of Soviet science and engineering in the late Stalinist period and in the Khrushchev era.

The history of Soviet science and technology has often been seen as closely intertwined with political history. Adhering to a Cold War-inspired "totalitarian model" of Soviet history, some historians have portrayed

Soviet science as a victim of pervasive control by the Party/state apparatus; the late Stalinist period in particular has been described as a time of the "triumph of ideology" over science.[12] But this image of science suppressed by political interference is hard to reconcile with the impressive scientific achievements of the Stalinist era, which earned Soviet scientists a host of Nobel Prizes in physics and chemistry. In the postwar period, scientific and engineering institutions and large-scale industrial and construction projects aimed at fulfilling Stalin's ambitious plan of the "great transformation of nature" mushroomed, and the Soviet Union celebrated an unprecedented "cult" of science and technology.[13] It was during this period that Soviet scientists built their first atomic and hydrogen bombs. Paradoxically, Soviet science appeared to thrive under Stalin's totalitarian rule better than in the relatively liberal climate of the Khrushchev regime. Indeed, the record of Soviet science seems to challenge the idea that democracy is vital to science. David Holloway has offered a solution to this paradox by describing Stalin's defense laboratories as "islands of intellectual autonomy," where political controls were relaxed and scientists could freely exchange ideas.[14] Loren Graham has agreed that science sometimes provided a refuge from the harsh reality of Stalinism; however, after comparing the amount of funding and government support for science and technology under Stalin with later periods, he concluded provocatively that money appeared to be more important than freedom in producing breakthroughs.[15]

While adherents of the totalitarian model take for granted a fundamental conflict between the Soviet scientific community and the Party/state bureaucracy, other historians emphasize various forms of ideological accommodation, pragmatic cooperation, and even institutional integration between different groups of scientists and politicians. Graham has dispelled the popular myth of Soviet scientists' being blinded by Marxist ideology and has shown how dialectical materialism, the official Soviet philosophy of science, was fruitfully integrated into the scientific outlook of many Soviet scholars.[16] David Joravsky has radically revised the traditional view of the struggle between Soviet geneticists and the followers of the ignoramus Trofim Lysenko as an "ideological" conflict, explaining it instead as a competition between rival groups of scientists and their patrons in various branches of the government apparatus.[17] Mark Adams has emphasized the role of "networks" of informal connections among scientists and between scientists and politicians, and described the relationships among the Party, the government, and the scientists in terms of negotiation rather than direct administrative pressure.[18] Nikolai Krementsov has further contended that "the control apparatus and the scientific community became fused not only in their overlapping organizational structures and networks, but also . . . in a common and quite peculiar set of shared images, rituals, and rhetoric," which led to their "cultural unification."[19] As a result of the gradual diffusion of cultural norms from the Party life into science, Alexei Kojevnikov has argued, Soviet scientists began to play "games of intraparty democracy": they reproduced public rituals of "criticism and self-criticism," and they framed political denunciations as "creative discussions" of scholarly matters. In this case, politics affected science through the subtle mechanism of discursive domination rather than through the brute force of administrative control.[20] The closer we look, then, the more complex the picture of the relationship between Soviet scientists and Soviet politicians becomes. Instead of a simple binary opposition, we have a confusing Möbius strip: it is no longer entirely clear who is on which side.[21]

Adherents of the totalitarian model view the use of ideological language in science as an example of distorted reflection of reality and tend to dismiss it as "ideologization" of science; social historians, on the other hand, often describe the role of language as purely pragmatic and instrumental. In this study, I do not draw a sharp line between "ideological" and "scientific" elements of academic discourse. Instead of viewing this discourse as a tool of totalitarian oppression or an unproblematic instrument of negotiation, I interpret it as a cultural medium in which Soviet scientists lived and worked. I agree with Stephen Kotkin that Stalinism was a "specifically socialist civilization" with its own language ("Bolshevik"), which not only gave the speaker access to power but also powerfully shaped the speaker's identity. "Stalinism was not just a political system, let alone the rule of an individual," writes Kotkin. "It was a set of values, a social identity, a way of life."[22] In this book I examine how newspeak and later cyberspeak became central to the "way of life" of Soviet scientists under Stalin and under Khrushchev.

In chapter 1, "The Cold War in Code Words: The Newspeak of Soviet Science," I explore the use of newspeak—the blending of scientific, philosophical, and ideological concepts—in political and academic discussions of the late Stalinist period. In particular, I examine how Soviet scientists used newspeak to balance the chief military and ideological priorities for postwar Soviet science: to "overtake and surpass" science in the capitalist countries and at the same time to "criticize and destroy" Western scholarship for its alleged ideological flaws. Both the "ideologization" and the "de-ideologization" of science appear as variable discursive strategies, rather than inherent features of Soviet science. This chapter traces ideological disputes in three disciplines—mathematics, linguistics, and physiology—in the late Stalinist period. An analysis of "floating signifiers"—such terms as *formalism* and *idealism*, which crossed the boundaries between scientific disciplines and between science and politics—provides an insight into the discursive mechanism of "scientific newspeak."

The emergence of cyberspeak in the "cybernetics circle" of American and European mathematicians, engineers, physiologists, sociologists, and philosophers in the 1940s is the subject of chapter 2, "Cyberspeak: A Universal Language for Men and Machines," in which I examine the divergent research paths of Norbert Wiener and Andrei Kolmogorov. I also discuss the contributions of Julian Bigelow and Arturo Rosenblueth, Claude Shannon and Warren Weaver, Warren McCulloch and Walter Pitts, Alan Turing, John von Neumann, and Erwin Schrödinger. These scientists and engineers not only produced diverse theories, models, and techniques of control and communication; they also introduced an array of new concepts that lay the foundation of cyberspeak. I trace the evolution of cyberspeak from a set of narrowly defined technical concepts to a "universal language" for men and machines and finally to the vehicle of a cybernetics bandwagon.

In chapter 3, "Normal Pseudo-Science," I examine the origins of the campaign against cybernetics in the Soviet press in the early 1950s in conjunction with the development of the first Soviet electronic digital computers. The first clash between newspeak and cyberspeak resulted in an ideological controversy over cybernetics' man-machine analogies and in attempts to "de-ideologize" Soviet computers. Contrary to the common view of the anti-cybernetics campaign as having been directed by Party authorities, I interpret it as a chain of events spontaneously generated by self-perpetuating Cold War propaganda discourse. The myth that this campaign significantly delayed the development of Soviet computers has already been dispelled, but the negative ideological image of cybernetics in the late Stalinist period did seriously narrow the range of the first Soviet computer applications. Soviet computing was shaped by the tension between the practical goal of building major components of modern sophisticated weapons and the ideological urge to combat alien influences. To shield themselves from potential ideological complications, computer specialists distanced computing from cybernetics and steered clear of computer modeling of biological and sociological phenomena. As a result, the digital computer was initially conceptualized in the Soviet Union as a giant calculator and stripped of all cybernetic metaphors.

In chapter 4, "Cybernetics in Rebellion," I explore the transition from Stalinism to the Khrushchev period in Soviet science through the prism of changing Soviet attitudes toward computing and cybernetics. During Nikita Khrushchev's political "thaw," cyberspeak openly challenged newspeak. The computer came to symbolize a new spirit of rigorous thinking, logical clarity, and quantitative precision, contrasting sharply with the vague and manipulative language of Stalinist ideological discourse. This chapter examines the cybernetics movement as a vehicle of de-Stalinization in Soviet science. Soviet cyberneticians sought a new foundation of scientific objectivity in the rigor of mathematical formulas and computer algorithms and in the "precise" concepts of cybernetics. In contrast to "scientific newspeak," they put forward a computer-based cybernetic criterion of objectivity as overtly non-ideological, non-philosophical, non-class-oriented, and non-Party-minded. The cyberneticians aspired to bring computer-based objectivity to the entire family of the life sciences and the social sciences by translating these sciences into cyberspeak.

In chapter 5, "The 'Cybernetization' of Soviet Science," I examine the Soviet cyberneticians' radical project of transforming a wide range of scientific disciplines along cybernetic lines. Soviet cybernetics emerged as an ambitious project for creating a single overarching conceptual framework, a general scientific methodology, a sort of substitute for the meta-scientific role of newspeak in academic discourse. Cybernetics began to serve as an institutional umbrella for various unorthodox research trends previously suppressed by dominant Stalinist schools. This chapter describes three such trends: "biological cybernetics" (genetics), "physiological cybernetics" (non-Pavlovian "physiology of activity"), and "cybernetic linguistics" (structural linguistics). In cybernetics' "trading zone," specialists from various disciplines attempted to communicate by means of a common language: cyberspeak. Initially, the flexibility of cyberspeak helped to establish the meta-scientific status of cybernetics and to bring a large number of disciplines under the umbrella of cybernetics. At the same time, this flexibility resulted in the wide diversity of cybernetic discourses and in the suspicious elasticity of cybernetic concepts. The increasing ambiguity of the language of cybernetics threatened to undermine the entire project of bringing formal rigor and exact reasoning to Soviet science.

In chapter 6, "Cybernetics in the Service of Communism," I document the climb of Soviet cybernetics to the height of official recognition and its concurrent fall to the depths of intellectual shallowness. After its inclusion in the 1961 Program of the Communist Party as one of the sciences crucial to the construction of communism, cybernetics became fully legitimized, officially recognized, and almost canonized. Inspired by their initial successes, Soviet cyberneticians set out to make cybernetics a "science of government." With limited political options, they tried to work out a mathematical solution to the political problem of reforming the Soviet economy. This chapter examines their ambitious proposals for nationwide "optimal" planning and management, and discusses the roots of opposition to such plans both from traditional political economists and industry executives and from radical reformer economists who were calling for the introduction of market mechanisms. After Brezhnev replaced Khrushchev, the academic and political establishment began to appropriate cyberspeak and computer technology as means of conserving the existing administrative hierarchies and power structures. Party ideologues developed the concept of "scientific management of society" with the help of cybernetic models and methods of control to ensure the stability of the Soviet economy and Soviet society. By the early 1970s, cybernetics had been transformed from a vehicle of reform into a pillar of the status quo. As cybernetic concepts acquired the generality and universality characteristic of other categories of official philosophy, cyberspeak began to resemble newspeak. Former cybernetics enthusiasts began to distance themselves from this official discourse and even stopped calling themselves cyberneticians. Cyberspeak and newspeak seamlessly integrated into "CyberNewspeak."

Emphasizing the close connections between language and theory, between knowledge and power, and between science and politics, I interpret newspeak and cyberspeak not as linguistic practices somehow imposed on Soviet scientists but as particular discursive strategies developed by scientists in their efforts to adapt to a specific political, ideological, and socioeconomic situation and to manipulate that situation to their advantage. I focus on the productive, rather than merely repressive, function of ideological discourse in Soviet science.[23] At the same time, I question Soviet scientists' complete mastery of either newspeak or cyberspeak, emphasizing the subtle ways in which language controls its "masters."

It is hard for historians of science to escape the conceptual domination of their subject matter: historians of biology often speak of "the evolution of ideas" and "the growth of science," historians of geology talk about "the shifting of the argument" and "the shaping of scientific knowledge," and historians of the physical sciences explore "the construction of science" and "the diffusion of knowledge." Although I have resisted the temptation to conceptualize the history of cybernetics as a self-organizing process controlled by feedback loops with the political and social context of science, the encroachment of cyberspeak, now spoken almost universally, has been hard to stop. It is no longer possible to avoid such common terms as *information*, *control*, *communication*, *code*, *signal*, and *feedback*, which have acquired their broad meanings through cybernetics. At least we now know where they came from.

1

The Cold War in Code Words: The Newspeak of Soviet Science

We have created in our press a special language—the language of a socialist citizen for a socialist citizen only. . . . This language is unfamiliar and sometimes unintelligible to the masses, even to the leftist masses, in the capitalist countries.

—from a classified report by a Soviet propaganda expert, 1946[1]

The leading Soviet specialist in mathematical logic—Sof'ia Ianovskaia, a professor at Moscow University—was a very experienced editor. A Bolshevik since 1918, in the 1930s she was trusted with an important political task: publishing the "mathematical manuscripts" of Marx. The manuscripts had not been published previously, for some mathematicians remained skeptical about their scholarly value. But Ianovskaia knew very well how to give the right ideological twist to a scholarly book and to disarm any potential critics. She discovered a great depth of dialectical thought in Marx's marginal notes, and she underscored their immense philosophical significance. Her experience came in handy in 1947, when she edited the Russian translation of David Hilbert and Wilhelm Ackermann's *Principles of Theoretical Logic*. To make the book more palatable to ideological watchdogs, she supplied a clever introduction, in which she distanced the book's authors from the unnamed "idealists parasitizing on mathematical logic." In addition, throughout the book she sprinkled dry logical formulas with a few lively examples of how mathematical logic could be relevant to socialism. Instead of using banalities like "all men are mortal," Ianovskaia illustrated logical expressions with philosophical maxims and familiar political slogans. Thus, she explained the concept of logical implication by using the vocabulary of dialectical materialism, the official Soviet philosophy of science:

Let us consider the following premises:

1. The answer to the basic question of philosophy, which concerns the relationship between thinking and being, can be either materialistic or idealistic.

2. The materialistic answer is incompatible with the idealistic one.
3. If the followers of Mach are telling the truth, their answer to the basic question of philosophy is neither materialistic, nor idealistic.

It is immediately obvious that a logical implication of this is as follows:

4. The followers of Mach are not telling the truth.[2]

Ianovskaia further demonstrated the power of formal language by representing the declaration "All Soviet women have equal rights with Soviet men" with the following formula:

For any object (or "any person") it is true that
if this object is a Soviet woman,
then this object has equal rights with Soviet men.[3]

Somehow this did not sound quite right. When formalized, revered philosophical dogmas and erstwhile sacred slogans turned hopelessly profane and sounded more like parodies. In 1950 the Russian edition of *Principles of Theoretical Logic* received a scathing review in the main Soviet philosophical journal *Voprosy filosofii* [*Problems of Philosophy*]. "Any mortal who is not intoxicated with formalism," the reviewers wrote, "can see that these exercises . . . lead to nonsense."[4] The reviewers brushed aside Ianovskaia's rhetoric and charged that Hilbert and Ackermann were marching "along the path of idealism and metaphysics, the path of further formalization of logic" and were "hiding their idealistic views behind specialized mathematical reasoning." Ianovskaia's efforts, in turn, were branded as a "*reconciliatory attitude toward idealism* in mathematics."[5]

Soviet scientists, entangled in the terrifying web of Soviet politics in the early years of the Cold War, learned to play by the rules of the establishment. Soviet scientists' close collaboration with the Party and with the government bureaucracy resulted in their gradual cultural adaptation to the behavioral patterns, modes of thought, and rhetorical styles of their patrons. Academic discussions were, more and more often, conducted in a language accessible to the bureaucracy: the value-laden ideological language of official Soviet discourse. This language constituted a pervasive ideological-linguistic medium in which Soviet scientists lived and worked.

Echoing George Orwell's original insight, I call this language *newspeak*. In his 1949 novel *Nineteen Eighty-Four*, a sharp and gloomy caricature of Stalinist Russia, Orwell coined this term to denote a particular socialist language that embodied a totalitarian world view and the "mental habits" of Party members. Newspeak made all alternative views impossible, since heretical thoughts would be "literally unthinkable."[6] After Orwell, *newspeak* became a popular analytical category in studies of Soviet public discourse. Newspeak reappeared time and again under the names *ideological language*, *official speech*, *Stalinese*, *totalitarian language*, *Communist speech*, *the Soviet language*, *authoritarian Russian*, and *langue de bois* [wooden language].[7] Several dictionaries of "Communist jargon" came out.[8] Soviet discursive practices, or specific ways of speaking, writing, and otherwise producing meaning, were diverse, and they evolved considerably over time. Without assuming the existence of a single, uniform, universally accepted language for the entire public discourse under Stalinism, I use *newspeak* in a narrow sense that refers specifically to the blending of scientific, philosophical, and ideological concepts in political and academic discourses of the late Stalinist period.

This chapter analyzes the dynamics of postwar Soviet science through the lens of the language of scientific debates. Instead of viewing scientific discourse as a mere servant of the state or a victim of totalitarian oppression, I focus on the productive, rather than repressive, function of newspeak in Soviet science. This chapter explores various discursive strategies developed by scientists themselves in their efforts to adapt to the current political, socioeconomic, and cultural situation, and to manipulate ideological discourse at the same time.

In the postwar period, Soviet scientists struggled to balance the chief military and ideological priorities for Cold War science: to "overtake and surpass" science in the capitalist countries and to "criticize and destroy" Western scholarship for its alleged ideological flaws. One popular strategy was to draw a boundary between the "objective content" of scientific knowledge and its philosophical meaning. Thus, I view the ideological disputes of the early 1950s not only as a clash of competing philosophical and ideological interpretations of particular theories but also as a contest over the exact position of the boundary between science and ideology.

Following Mark Adams, I interpret Soviet ideology not as an essential set of beliefs somehow imposed on the scientific community from above but as a flexible language of negotiation involving the Party, the government, and the scientists.[9] Using the tetrad model of the Soviet "ideolanguage" developed by Mikhail Epstein, I attempt to elucidate the discursive mechanisms of newspeak.[10] In contrast to Orwell, I emphasize the flexibility rather than the rigidity of this ideological language. Newspeak did not simply express some pre-established orthodoxy; quite the opposite, the skillful use of newspeak allowed one to manipulate ideology and, to some extent, to define what was permitted in a Soviet context. A manifestly dogmatic and at the same time strikingly flexible language, newspeak did not embody the truth; it provided mechanisms for negotiating the truth.

The ideological language of the postwar period had two major components, two rich repertoires, which complemented each another: the political language of the Cold War and the philosophical language of dialectical materialism. Philosophical terminology served as a bridge between the scientific and the political. It was used not only by the professional philosophers who served as ideological watchdogs of the Soviet academic community, but also by scientists themselves. By learning newspeak, scientists acquired necessary rhetorical tools for refashioning scientific ideas, legitimizing their own position and discrediting their opponents.

The interplay of various discursive strategies of newspeak is illustrated by case studies of ideological disputes that occurred in three scientific disciplines—mathematics, linguistics, and physiology—in the late Stalinist period. Despite the vast intellectual differences among these disciplines, in all three cases Soviet scientists employed very similar strategies to translate their intellectual disagreements and institutional squabbles into principled ideological conflicts. Newspeak became a common language for Soviet mathematicians, linguists, physiologists, philosophers, and politicians.

Balancing Military and Ideological Priorities for Cold War Science

In March of 1954 researchers of the Mathematical Institute of the Soviet Academy of Sciences in Moscow were preparing a comprehensive book-length survey of the entire mathematical discipline, *Mathematics: Its Content, Methods, and Significance*. An Institute-wide "philosophy seminar," whose mission was to instill the right ideological principles into the researchers' minds, held a special session devoted to the discussion of a draft introduction to the book. One of the discussants displayed heightened ideological vigilance and proposed to de-emphasize in the introduction the contributions of American mathematicians. "There is no progressive science or progressive music in America now," he argued. "They have lured in a number of scientists from all over the world, and now barely manage to maintain their military potential. We will not promote American mathematics."[11] Another participant voiced a different opinion: "There are some progressive-minded people [in the United States], and one should not lump them together with the Wall Street," he said. "A great majority of American mathematicians have come out of the ordinary folk and do not represent the American monopolistic bourgeoisie."[12] The question how to treat science produced by a Cold War enemy—as a value-neutral body of knowledge or as an ideological Trojan horse—acquired central importance in Soviet public discourse on Western science in the early years of the Cold War.

In the murky waters of Cold War politics, Soviet scientists and engineers were caught between the Scylla of the national defense and the Charybdis of ideological purity. In February of 1946 Stalin personally formulated as the chief priority for Soviet science "not only to overtake but to surpass in the near future the achievements of science beyond the borders of our country."[13] Soviet scientists and engineers were instructed to catch up with the West in the shortest possible time, particularly in nuclear physics and rocketry. In the cases of the first Soviet nuclear bomb and the first rocket, the Soviet leaders, distrustful of domestic scientists' abilities, chose the path of directly copying Western exemplars. At the same time, paradoxically, Party ideologues urged Soviet scientists to treat Western scholarship as "idealistic and reactionary." The Cold War was fought not only on the international scene but also on the "home front"—against any real or imaginary opposition to the chosen political course of international confrontation. After brief period of ideological relaxation and active cultural contacts among the Allies during World War II, Soviet authorities began to tighten ideological screws, cutting off international contacts and trying to bring intellectuals in line with the Party policy. In April of 1947, Agitprop—the Department of Agitation and Propaganda of the Party Central Committee—issued a secret "Plan of Measures for the Propagation of Soviet Patriotism among the Population." In August of 1947 *Literaturnaia gazeta* demanded that several Soviet scientists be brought to "public court" for their "lack of patriotism." A few days later *Pravda*, the main Party mouthpiece, criticized several leading scientists for "unpatriotic acts" and "servility to the West"—crimes that consisted largely of publishing articles in foreign periodicals. In March of 1949 the Politburo set the ideological priorities for the second edition of the *Great Soviet Encyclopedia*, urging the authors to "criticize from the Party position modern bourgeois trends in science and technology."[14] In May of 1952 the Academy of Sciences

Institute of Philosophy promised "to criticize and destroy all reactionary philosophical trends that appear in bourgeois countries under new, modish names and spread the propaganda of a new war."[15]

Soviet scientists and engineers faced a fundamental dilemma. Soviet scientific progress was measured against Western science, though the same Western science was also branded in public discourse as a source of alien ideology. Both priorities—"overtake and surpass" and "criticize and destroy"—featured prominently in Soviet public discourse. This created a permanent unresolved tension; it also created considerable confusion. One could hardly obey both orders at once, following the Western path while moving in the opposite direction. To "overtake and surpass" Western science, Soviet scientists needed to borrow Western knowledge; if they borrowed, they could easily be accused of "kowtowing" before the West. However, completely disregarding the latest trends in Western science could be seen as a deliberate attempt to slow down Soviet science and to put it behind its Western counterpart. The historian David Joravsky has pointed out the absurdity of this situation:

> The need to overtake and surpass the West coexisted with the need to stop kowtowing to the West, each inflaming the other. However inconsistently, the Stalinist mentality laid both demands on scientists, to be true to their own Russian knowledge and to surpass Westerners in universal knowledge; to take a rock-solid stand in the native monolith and to be as disputatiously creative as scientists in the West.[16]

Soviet discourse on Western science thus became saturated with paradoxes. Soviet authors often dismissed a Western-born scientific theory as bourgeois nonsense and in the same breath claimed national priority in elaborating the very same theory. Soviet leaders, distrustful of Soviet scientists, tended to support scientific and technological innovations only if they were recognized in the West. At the same time, Western reports were often regarded as a source of false information intended to mislead Soviet scientists and put them on the wrong track; it was assumed that a really worthy idea would not be advertised in the open press.

In the fragmented and contradictory ideological discourse of the late Stalinist period, there was no general rule for politically correct behavior. In every particular situation, Soviet scientists had to choose between two alternative slogans: "Criticize and Destroy!" and "Overtake and Surpass!" This was not simply a choice of rhetoric; it implied a radical change in their vision of science, and it had profound epistemological implications. The followers of the "criticize and destroy" approach viewed knowledge as ideological through and through, and therefore they regarded any scientific theory born in a capitalist society as an expression of "reactionary, imperialist ideology" by definition. In contrast, the champions of the "overtake and surpass" strategy did not regard Western science as an ideological threat. They assumed that scientific knowledge was "objective," value-neutral, and universal across political borders.

The slogan "Criticize and Destroy!" was taken up by the supporters of Trofim Lysenko, who discarded much of contemporary Western knowledge and attempted to build a distinct, ideologically superior socialist science. In July 1948 Lysenko delivered his infamous address "On the Situation in Biological Science," in which he contrasted two "opposing and antagonistic" trends in biology. He labeled the first trend (Western-born "Weismannism-Mendelism-Morganism," which lay at the basis of modern genetics) unscientific, idealistic, metaphysical, reactionary, scholastic, feeble, and sterile. As a healthy alternative, Lysenko put forward his own doctrine, a variation on the Lamarckian idea of the inheritance of acquired characteristics, which he praised as truly scientific, materialistic, creative, productive, and progressive. He patriotically called this doctrine "creative Michurinist Darwinism," tracing its roots to a Russian "founding father": the agronomist Ivan Michurin. Caught in a fierce battle for the control over Soviet biological research and educational institutions, Lysenko painted his opponents—Soviet geneticists and evolutionary biologists—as enemies of Soviet ideology. Emphasizing the Western origins of his opponents' work, he dubbed them "Morganists," attacked them for their alleged philosophical and ideological errors, and even attached political labels to them.[17]

Stalin himself edited Lysenko's address, bringing its rhetoric in line with the ideological priorities of the unfolding Cold War. Initially, Lysenko relied on the criterion of class to divide science into the "Soviet" and "bourgeois" kinds; this principle, popular among Soviet Marxists in the 1920s and the 1930s, was now completely obsolete. During the war, in the spirit of cooperation between the Allies, it had been supplanted by proclamation of the unity of international science. The dawning of the Cold War invalidated this thesis too. Stalin went over Lysenko's manuscript scrupulously and replaced the obsolete references to "bourgeois" scientific theories with the words *idealistic* and *reactionary*; he also substituted *scientific biology* for *Soviet biology*.[18] Stalin's revisions signaled a discursive turn from class-based analysis of science to the concept of "two worlds—two ideologies in science"—an idea that was much better suited to the tasks of Cold War propaganda.

An opposite attitude toward Western science—one based on the Party slogan "Overtake and Surpass!"—was expressed by Soviet defense physicists concerned with closing the "nuclear gap." The atomic bomb, then the most potent symbol of political and military power, effectively rendered Western physics legitimate in the eyes of Soviet officials. This may have played a decisive role in resolving an ideological controversy over quantum mechanics and relativity theory—a conflict that was stimulated by the institutional rivalry between physicists from the Academy of Sciences and physicists from Moscow University. In 1949 the Academy physicists reportedly prevented an ideological pogrom in physics by claiming the importance of these Western-born theories for the construction of nuclear weapons. The University physicists, who chose to trumpet the "Criticize and Destroy!" slogan, found that their ideological arguments had little weight against the bomb.[19] The relationship between science and ideology in the postwar period was not fixed; it varied from discipline to discipline, and it was often hotly contested.

Shifting Boundaries between Knowledge and Ideology

The followers of the two opposite approaches—"to criticize and destroy" and "to overtake and surpass"—developed distinct discursive strategies to legitimize their views of the relationship between knowledge and ideology. Both groups drew on Marxist theory; however, playing on the complexity and the inconsistency of the Soviet interpretation of Marxist philosophy of science, they evoked different aspects of it. This interpretation paradoxically combined social constructivism (science as a product of socioeconomic and political forces) with scientific realism (science as objective truth about nature).[20]

The first group, best represented by Lysenko and his followers, attempted to "ideologize" science by translating scientific theories into an explicitly ideological language. They rendered their own theories into Marxist philosophical and political terms. The theories of their opponents, on the other hand, were labeled as philosophical and political deviations from Marxism. The "ideologizers" thoroughly traced their opponents' views to Western-born scientific theories—an embodiment of alien ideology—and thus made them an easy target of ideological attacks under the slogan "Criticize and Destroy!" It was precisely this type of discourse that prompted historians to speak of the essential "ideologization" of Soviet science in the late Stalinist period.

In the late 1940s and the early 1950s, a series of vociferous ideological campaigns dominated by the "criticize and destroy" trend swept Soviet science. Lysenko's proclamation of the uncompromising struggle between socialist and capitalist trends in biology set an example for the rest of Soviet science. In August through December of 1948, meetings discussing the new line were held in numerous research and educational institutions across all disciplines. Mathematicians, physicists, geologists, and astronomers all were now supposed to expose "idealistic and reactionary" elements in their academic fields. In early 1949 a widespread campaign against "cosmopolitanism" (an ideological label for anti-patriotism and "kowtowing before the West") began. That campaign was accompanied by vicious anti-Semitic attacks and by the expulsion of Jews (labeled "rootless cosmopolitans") from many cultural and academic institutions.[21] These campaigns destroyed careers and effectively banned whole areas of research; in a number of disciplines, the most dogmatic trends prevailed, imposing narrow conceptual frameworks and stifling creative thought.[22]

In postwar ideological campaigns, the boundary between academic debate and political dispute was completely erased. Philosophical categories that denoted various deviations from dialectical materialism (the official Soviet philosophy of science) mixed with political clichés of Cold War propaganda. Discussions of genetics, relativity theory, quantum mechanics, and various Western-born theories in economics, chemistry, physiology, linguistics, and mathematical logic became saturated with the pejorative labels *idealism*, *mechanicism*, *metaphysics*, *formalism*, and *cosmopolitanism*.[23] Campaign activists often reduced Western scientific knowledge to philosophical errors and further to ideological and political mistakes. Soviet scientists who saw in Western science a rational, "objective" kernel opposed this trend. Insisting on the value-neutral, impartial character of scientific knowledge, they elaborated an alternative strategy of "de-ideologization" of science. They ingeniously split Western scientific theories into two presumably independent parts: the ideologically neutral and objective "core" and the ideology-laden philosophical "shell." The "de-ideologizers" tried to rescue what they saw as the "essential" elements of Western theories while sacrificing only the "dispensable" ones. They freely "criticized and destroyed" the latter while safely adopting and further developing the former. The "de-ideologization" strategy gradually shaped a popular image of science as a centaur with a solid body of scientific facts and a manifestly political face, socialist or capitalist.

In their defense of quantum mechanics and relativity theory from ideological critique, the Academy physicists often resorted to the "de-ideologization" strategy. For example, they insisted on the mathematical correctness of the uncertainty principle, but they cautiously distanced themselves from the controversial Copenhagen interpretation. At the same time, they worked hard to elaborate an acceptable philosophical interpretation of quantum mechanics so as to bring it into harmony with dialectical materialism.[24] The "de-ideologization" strategy also profoundly influenced contemporary Soviet writings on the history of science and technology.[25]

Different authors not only offered competing philosophical and ideological interpretations but also disputed the exact location of the boundary between scientific knowledge and ideology. For example, the localization of the physical principle of complementarity was hotly contested. Militant philosophers claimed that this principle was a part of the "philosophical interpretation" and therefore belonged to their professional domain; they argued that this principle was "idealistic" and therefore false. The Academy physicists, on the other hand, tried to present it as a part of the core theory and offered an alternative materialistic interpretation. The boundary between the scientific "core" and the ideological "shell" was constantly shifting back and forth, depending on who was drawing it.[26]

Remapping science—drawing a boundary between knowledge and ideology—was not only an epistemological task; it was also political activity. It effectively delineated the spheres of authority between scientists and nonscientists and between politicians and professional ideologues. Throughout Soviet history, these spheres were redefined many times, and epistemological boundaries were redrawn accordingly. The relative intellectual autonomy of scientists in the early Soviet period was followed by the increasing involvement of politicians, government officials, and philosophers in resolving scientific disputes during the Stalin era.[27] Depending on the position of their Party and government patrons, competing groups of scientists constantly shifted the knowledge/ideology boundary back and forth, trying either to invite or to prevent the authorities' intervention. Because of the tensions inherent in postwar politics, this boundary could never be fixed. Perhaps all sides had a stake in maintaining this discursive flexibility, for it allowed them substantial room to maneuver.

The postwar ideological campaigns affected all Soviet scientists, and political rhetoric became truly pervasive. Both the "ideologizers" and the "de-ideologizers" spoke the Stalinist ideological language. The first group attempted to translate entire scientific theories into this language, while the second limited its uses to the discussion of "philosophical interpretations" of those theories. Fluency in this language, which I will call *newspeak*, became one of the prerequisites for scientific work. Newspeak provided potent discursive strategies for linking science to philosophy to politics, and it allowed a skillful speaker to attach political labels to any scientific target.

Newspeak: The Fundamentals

Newspeak allowed a seamless transition from science to philosophy to ideology, for its vocabulary was composed largely of "empty" or "floating" signifiers—words that easily passed between different realms and were (re)filled with different meanings.[28] For example, as the political scientist Rachel Walker has argued, *Marxism-Leninism* could appear in different contexts as "an ideology, a science, a morality, a theory, a philosophy, a political practice, a sociology, an economics, a party line, and so on."[29] This term could acquire wide currency and become truly pervasive precisely because of its capacity to accommodate a broad range of meanings:

> "Marxism-Leninism" is an empty signifier: a word which means everything and nothing, a word which has no intrinsic meaning, no ontological and epistemological entailments, no necessary and essential relationship with any of the ostensible objects with which it has been conventionally associated—whether these be a general "body of ideas," a social value system, or the theoretical output of two historical individuals named Marx and Lenin. This is not to argue that the word is entirely incapable of meaning, but rather to suggest that any meanings predicated on it are contingent—they shift and change according to context and usage.[30]

Words of newspeak easily crossed contextual boundaries, but they did not walk value-free. These words blended description with evaluation: they did not simply name things, but passed a strong positive or negative value judgment about them. For example, *Marxism-Leninism*, whatever it meant, always carried a positive evaluation, while such words as *idealism*, *metaphysics*, and *formalism* could refer to a wide range of scientific and philosophical doctrines but always labeled them negatively. The cultural theorist Mikhail Epstein has called such words "ideologemes":

> Ideologemes, being the elementary particles of ideological thinking, are not simply words, but concealed judgments that take the form of words. Usually a judgment is developed in an entire sentence, where it is divided into a subject and predicate. This kind of judgment is open to discussion because the link between subject and predicate is explicitly relative. . . . The factual meaning of the ideologeme usually serves as the subject of the judgment, the evaluative meaning, as the predicate. . . . An ideologeme is nothing other than an idea that is hidden in one word (or, sometimes, in one indivisible phrase or idiom). In this way it can be inserted into the listener's consciousness without the possibility of argumentation or objection. One cannot quarrel with a single word.[31]

For example, newspeak reduced the explicit assertion "Striving for peace in this situation is wrong" to the simple label "conciliatoriness," which already embodied a negative judgment. Ideologemes resembled what Orwell called "words which had been deliberately constructed for political purposes" and "a sort of verbal shorthand, often packing whole ranges of ideas into a few syllables."[32]

Since ideologemes have dual (descriptive and evaluative) meanings, the relations between them are more complex than relations between ordinary words. Instead of simple synonymy and antonymy, ideologemes can relate to one another in four different ways.

The first way, full antonymy, denotes the opposition of both the descriptive and the evaluative meanings. Such binary oppositions as socialism vs. capitalism, proletariat vs. the bourgeoisie, freedom vs. slavery (or oppression), internationalism vs. nationalism (or chauvinism), and collectivism vs. individualism were characteristic of early Marxism. They embodied a Manichean vision of the world deeply divided into two antagonistic and irreconcilable camps.[33]

Relationships of the second type involve pairs of words with synonymous descriptive meanings but opposite evaluations. The same concept is expressed in different words, depending on whether one is talking about a friend or an enemy. For example, the word *spy* could refer only to the enemy's intelligence officers, and never to our own agents.[34] Different vocabularies are used to describe similar actions of socialist and capitalist governments and to characterize comparable activities of the "revolutionary avant-garde" and its "class enemies." What in our case is called "peacefulness" is in their case labeled "conciliatoriness"; what in one context is hailed as "internationalism" is branded "cosmopolitanism" in another; our "loyalty to principles" translates into "dogmatism." As concepts travel from one ideological context to another, their ideological coloration changes accordingly: positive evaluative meanings are turned into negative ones, and vice versa.

Pairs of ideologemes with similar (either strictly positive or strictly negative) evaluations but opposite descriptive meanings belong to the third type. For example, both members of such pairs as internationalism and patriotism, peacefulness and irreconcilability, and tradition and innovation have equally positive connotations. By contrast, both parts of such oppositions as idealism vs. mechanicism, subjectivism vs. objectivism, and formalism vs. naturalism bear equally negative evaluation. By placing strong emphasis on evaluation, newspeak helps mask contradictions in ideological discourse. Thus, one can claim to be at once an internationalist and a patriot, or one can accuse an opponent of deviating from dialectical materialism in two opposite directions (e.g., toward idealism and toward mechanicism) at the same time.

The fourth type of relationship connects fully synonymous ideologemes, which can be freely substituted for one another. For example, discipline is identified with organization and consciousness, while permissiveness is associated with lack of control and anarchy. By constructing series of synonymous ideologemes, newspeak provided political "supplements" to philosophical semantics and philosophical "supplements" to political semantics.[35] Thus, one could easily jump from science to politics by translating scientific, philosophical, and political concepts into synonymous ideologemes. In this way, Lysenko skillfully connected his "agrobiology" with dialectical materialism and with socialism and at the same time linked genetics to idealism to capitalism. Lysenko's doctrine was thus effectively portrayed as a socialist science, while genetics was labeled as a product of capitalism. By linking scientific, philosophical, and political concepts into chains of ideological synonymy, one could blow up a smallest flaw into a major political mistake, and turn an intellectual opponent into a principled political enemy. For example, in 1940 the militant Marxist philosopher Ernest Kolman stepped into the dispute between Lysenko and the prominent Soviet mathematician Kolmogorov over the use of statistical methods in biology. Kolman skillfully built a chain of ideological associations—from Kolmogorov to the German mathematician Richard von Mises (because both of them worked on probability theory), then from von Mises to the Austrian philosopher Ernst Mach (because von Mises cited Mach in his work), and finally from Mach to "subjective idealism" (which Lenin himself had branded as a major deviation from dialectical materialism).[36] Kolmogorov thus ended up in a subjective idealistic hole, and this smelled of a grave political error. The construction of ideological synonymy served not only as a powerful rhetorical tool of criticism, but also as a convenient propaganda device. As the historian Stephen Kotkin has observed, one could appeal to various groups by appropriately shifting the emphasis from one "mobilizing phrase" (such as *Soviet*, *socialism*, *Bolshevism*, or *Marxism-Leninism*) to another, since all of them functioned as ideological synonyms.[37]

Ideologemes related by synonymy or antonymy of their descriptive or evaluative meanings could be organized into tetrads (figure 1.1).[38] In every tetrad, both words in the left column have positive evaluations, even though their descriptive meanings are opposed (internationalism and patriotism). The descriptive meanings of both words in the right column are also opposed, but this time they have negative evaluations (cosmopoli-

internationalism — cosmopolitanism
patriotism — nationalism

freedom — anarchy
discipline — repression

peacefulness — appeasement
irreconcilability — aggressiveness

innovation — avant-gardism
loyalty to tradition — backwardness

pragmatism — bendiness
loyalty to principles — dogmatism

Figure 1.1

tanism and nationalism). Both words in each row have identical descriptive meanings but opposite evaluations. For example, an equal love for all nations can be either ideologically approved (internationalism) or disapproved (cosmopolitanism); similarly, an exclusive love for one's own nation can be evaluated either positively (patriotism) or negatively (nationalism or chauvinism).

Manipulations with ideologemes within each tetrad give newspeak enormous flexibility. Through a series of substitutions, contrasts, and conversions, one can easily provide an ideological justification or refutation of any position that can be formulated in tetrad terms. Any tetrad concept can be turned into its opposite, as Orwell so vividly illustrated in the famous slogans inscribed on the façade of the Ministry of Truth[39]:

War is Peace
Freedom is Slavery
Ignorance is Strength

For example, one could start with the ideologeme "freedom," substitute its evaluative synonym "revolutionary discipline," then equate that with "revolutionary violence," convert that into "repression" (different evaluations, but similar denotations), and finally replace "repression" with "slavery."[40]

Newspeak turned elements of various political slogans, which were introduced in different historical periods and reflected tortuous paths of Bolshevism, into "floating" or "empty" signifiers. They could be filled with any content, descriptive or evaluative, depending on the intentions of the speaker. For example, the binary opposition "internationalism vs. nationalism," characteristic of early Marxist ideology, was widely employed in early Soviet years to support the dream of a "world revolution." During World War II, however, the ideological emphasis was switched to "patriotism," which in postwar years formed a stable binary set with its ideological opposite, "cosmopolitanism." The political culture of late Stalinism did not eliminate the first opposition but instead combined it with the second to form a flexible ideological tetrad. If political expediency demanded that postwar cooperation with the Western Allies be ideologically condemned, the proponents of such cooperation could be labeled "cosmopolites"; if the opposite view was expedient, the opponents of such cooperation could easily be branded as "chauvinists." A cunning newspeak adept like Stalin could thus use "leftist slogans to defeat the right, rightist slogans to defeat the left."[41]

Thanks to the flexibility of newspeak, virtually any position could be rendered ideologically flawed, and anyone could be painted as an ideological enemy. As Epstein argues, the "speaker who controls the tetrad does not so much participate in conflicts as he uses them, playing upon their contradictions."[42] As Walker has argued, there was no safe ideological position in Soviet politics:

> The result is a "Catch-22" which keeps the whole community to which [the term *Marxism-Leninism*] is addressed in a state of perpetual tension since this community can never predict exactly what behavior, what "interpretation" of "Marxism-Leninism," will be correct at any point in time. To defend the "purity" of Marxism-Leninism is to risk being labeled a "pendant" or a "dogmatist." To creatively develop it is to risk being labeled a "revisionist" or some sort of "deviationist." To be seen doing neither is to risk the accusation of not being a Marxist-Leninist at all.[43]

The inherent uncertainty of the Soviet ideological discourse both created room for maneuver and made any maneuvers potentially dangerous: one had to repeat dogmas without sounding dogmatic, and to show originality without introducing too much novelty. It is not difficult to find some similarities between these techniques and the rhetorical devices used by scientists, who often paradoxically combine the claim of "organized skepticism" with a firm commitment to the dominant paradigm.[44] Although "science" is often perceived as an opposite of "ideology," in the Soviet case the language of science proved inextricably linked with newspeak.

Scientific Newspeak

Newspeak was not just the language of Party bureaucracy; it permeated the entire public discourse of Stalinist society, and it became a pervasive medium in which Soviet scientists lived and worked. As the role of Soviet science in national defense, in industry, and in agriculture gradually grew, Party and government officials began to serve as referees of scientific disputes. Soviet philosophers, who since the 1930s had been involved in the ideological policing of the scientific community, often served as mediators between scientists and politicians, translating scientific theories into ideological language for the politicians and transforming political slogans into research agendas for the scientists. Newspeak emerged at the nexus of scientific, philosophical, and political discussions, tying them inextricably together. Newspeak became a language of negotiation for Soviet scientists, philosophers, politicians, and government officials, providing a means for seamlessly translating science into philosophy into ideology into politics and vice versa.

Under Stalin, dialectical materialism, once a thriving and productive field of philosophical scholarship, turned into an official canon, gradually "calcified," and began to serve as a philosophical cudgel.[45] In the ideological battles of the 1930s and the 1940s, the basic principles of dialectical materialism (realism; nonreductionism; the view of the material world as an infinitely complex, interconnected, and evolving whole; belief in the relative nature of human knowledge) were often subjected to the most dogmatic interpretations.[46] Doctrinaire thinkers identified "the material world" with entities directly observable with contemporary scientific instruments; everything else, including genes, was labeled as the product of "idealistic" speculation. At the same time, the categories of dialectical materialism and the three laws of dialectics (the transition of quantity into quality, the unity and struggle of opposites, and the negation of the negation) acquired great "elasticity," which allowed one to bend philosophical argument in any direction. After making numerous twists while attempting to catch up with the winding Party line, Soviet philosophy of science finally degenerated into a complex rhetorical system that combined ostentatious adherence to the canonical formulas of Marx and Lenin with extremely flexible techniques of cunningly reinterpreting those formulas to make them fit the political agenda of the day. Such philosophical oppositions as "materialism vs. idealism," "dialectics vs. metaphysics," and "practice vs. formalism" acquired strong political connotations in the Soviet academic discourse in the late Stalinist period. The second (negative) term in each pair did not simply denote alleged philosophical flaws in the opponent's argument; it also labeled the opponent as an ideological deviant and a potential enemy. As figure 1.2 illustrates, dialectical materialism became a part of newspeak, a convenient rhetorical tool for translating scholarly debates into ideological and ultimately political conflicts.

Both the scientists and the Party and state officials showed genuine creativity in using the discursive techniques of "quotation-mongering" (fetching a supporting quote from the canonical writings of Marxist "classics") and "label-sticking" (painting the opponent as a political or philosophical deviationist).[47] Stalin's technique of accusing his political opponents of deviating from the (constantly changing) Party line echoed in the disputes

materialism — mechanicism
consciousness —— idealism

stable categories —— metaphysics
dialectics — speculative dialectics

objectivity ———— objectivism
Party-mindedness — subjectivism

practice ——— naturalism
generalization —— formalism

practicality ———— utilitarianism
theory — knowledge for its own sake

Figure 1.2

between the Lysenkoites and geneticists over the interpretation of Darwinism and in Pavlov's disciples' competing claims to his legacy. The debates over who was a "true Darwinist" or a "true Pavlovian" were modeled after the struggle for the right to be called a "true Leninist." In a truly postmodern fashion, both sides in such disputes jiggled "classical" quotations to prove their exclusive connection with the sacred source of scientific/political authority. Some scholars even kept elaborate catalogues of Marxist quotations for any occasion.[48] The philosophical/political labels scientists were trying to stick to their opponents were also parts of the regular Party lexicon.

The emergence of scientific newspeak as a fusion of scientific and political discourses was a part of the general "cultural unification" between scientists and their Party and government patrons in the late Stalinist period.[49] As a new elite group, Soviet scientists began to play "games of intraparty democracy," to model scientific conferences after Party meetings, to reproduce the public rituals of "criticism and self-criticism," and to frame political denunciations as "creative discussions" of scholarly matters.[50] Ideological language was not just an instrument of scientists' interaction with the state; to a large extent, newspeak was the product of this interaction.

Both professional ideologists and scientists contributed to the expansion and the sophistication of newspeak's uses. Not only did the scientists borrow terms and rhetorical tools from the Party lexicon, but the Party and state officials were also striving to speak "scientifically." Officially approved scientific doctrines, such as Lysenkoism and Pavlovianism, entered the newspeak canon and provided models and terminology for public discourse far beyond their disciplines. Images and metaphors circulated back and forth between the realms of politics and science.

In the late Tsarist and early Soviet periods, Communist ideology drew its legitimacy in part from its claim of being "scientific," thus in fact placing science on an even higher pedestal than itself. It was somewhat ironic, but historically quite logical, that the roles reversed when Communist ideology was firmly installed in its supreme position: now science had to draw its own legitimacy from the claim of its complete compatibility with this ideology. Both the Marxist ideologists and the scientists seemed quite content with this circular argument: Marxism is correct because it is scientific; Soviet science is correct because it is Marxist. Ideologists interpreted this formula as the affirmation that Marxist ideology was the supreme judge of scientific truth; they made it the foundation of the so-called principle of "Party-mindedness" of science. Scientists, by contrast, often construed it as the assertion of the inherent affinity between science and Marxism, as they were both based on the same rational foundation. Sergei Vavilov, president of the Soviet Academy of Sciences, came up with a cunning formula: The Party-mindedness of science is "the expression of its correctness."[51] As the historian Alexei Kojevnikov has observed, this statement could be read either as an affirmation that Party-mindedness was vital for attaining correct knowledge or as an assertion that correct scientific theories would certainly be useful for socialist construction and should therefore be regarded as "Party-minded."[52] Scientists who preferred to elude ideological watchdogs and to use their own criteria of scientific validity, of course, favored the latter interpretation.

Like many other national languages in the twentieth century, the Russian language dramatically expanded its vocabulary with new scientific and technical terminology. As the literary critic Andrei Sinyavsky argued, newspeak turned these terms into political symbols:

Everyday speech is full of these "beautiful" words, such as *mechanization, industrialization, electrification, melioration, chemicalization, aviation, radio, antenna,* *accumulator, commutator, automat, cadres,* et cetera. These terms [imply] some greater meaning. Behind the word *cadres,* one hears Stalin's famous dictum "The cadres decide everything"; and behind the word *electrification,* the Leninist formula "Socialism equals Soviet power plus the electrification of the entire country."[53]

Newspeak borrowed from the language of science not only florid terminology but also a whole set of rhetorical devices that helped create the impression of objectivity. Both languages favored an impersonal style, avoided verbs, used an excessive number of nouns, and were well suited for generalizations and decontextualized, timeless proclamations.[54] Newspeak, for example, deliberately excluded the first person pronoun *I*, replacing it with the collectivist *we*, in much the same way as scientists often let "facts speak for themselves" instead of providing a personal account. As in scientific discourse, which is marked by an elaborate classification of entities, newspeak piled up nouns on top of one another, essentializing ideological constructs and increasing the social distance between the author and the listener.[55] In short, newspeak aspired to what the Soviet dissident Aleksander Zinov'ev has dubbed the "scientoid" style.[56]

Clever manipulation of ideologemes allowed one to translate science into philosophy into politics in many different ways. Rival groups of scientists translated the same scientific theories into opposite ideologemes. They rendered their own scientific theories into positive ideologemes, such as "objectivity," "practicality," "dialectics," and "materialism." At the same time, they translated their opponents' theories into negative ideologemes, such as "objectivism," "utilitarianism," "idealism," "mechanicism," and "metaphysics." The outcomes of scientific disputes often hinged on the disputants' mastery of newspeak and their ability to perform an ideological translation. The fundamental indeterminacy of ideological translation, however, often made it difficult to predict which translation would work better and which side in an ideological debate would win.[57]

Three case studies of ideological disputes in mathematics, linguistics, and physiology are discussed below. Despite the vast differences in the intellectual contents of these disciplines, Soviet scientists resorted to very similar discursive strategies in their attempts to translate science into politics in all three cases. Rival groups transformed their intellectual disagreements and institutional squabbles into principled ideological conflicts. Academic discussions in various disciplines were conducted within a unified philosophical/ideological discourse that revolved around such concepts as "idealism" and "formalism." Mathematicians, linguists, physiologists, and politicians found a common language: newspeak.

"Formalism" as a Floating Signifier

The "floating signifiers" of newspeak not only changed meanings in different contexts but also carried "traces" of meaning from one realm to another. They easily crossed boundaries between scientific disciplines and various spheres of culture. If a term acquired a strong positive or negative ideological evaluation in one field, it carried this value into other domains. *Formalism* became a particularly pervasive word, encompassing a wide range of negatively evaluated phenomena in various fields of science and culture.

When Soviet critics castigated Hilbert and Ackermann's book *Principles of Theoretical Logic* for formalism, they purposefully attached an ideological label to a technical term. Among the mathematicians, Hilbert's school of mathematical thought had been internationally known as formalism. This school emerged in the early twentieth century as one of the three major approaches to the foundation of mathematics. Hilbert's formalism aspired to apply the axiomatic method of Euclid's geometry to other branches of mathematics, treating mathematical theories as totalities of formulas written in accordance with arbitrarily defined formal rules without any reference to the meaning of these formulas. Formalists thus derived the validity of mathematical theories from the consistency of the formal language of mathematics. Two alternative approaches to the foundation of mathematics were intuitionism and logicism. Intuitionism, introduced by the Dutch mathematician L. E. J. Brouwer, contended that the basic objects of mathematics were mental constructions governed by self-evident laws. Intuitionists thus accepted only those mathematical axioms and rules of inference that they intuitively perceived as true, dismissing the arbitrarily defined formulas of the formalists as mathematically meaningless. Logicism was developed by the German mathematician Gottlob Frege and the British mathematician Bertrand Russell. They attempted to deduce mathematics from purely logical principles without using any specifically mathematical concepts, such as set or number. Back in the 1930s, Soviet mathematicians discussed formalism, intuitionism, and logicism as important mathematical trends without attaching to them any particular ideological labels.[58]

The word *formalism* acquired a much more ominous meaning during the militant debate over the interpretation of Marxist philosophy in 1930. One group of Marxist philosophers accused another of “formalistic views and errors,” which consisted in “the repetition of abstract formulas instead of solving concrete problems posed by life itself.”[59] The accused charged that their opponents were themselves guilty of “formalistic deviations,” and qualified formalism as an “idealistic” departure from dialectical materialism. “The formalistic perversion of materialistic dialectics,” they wrote, “is in essence an idealistic revision of Marxism.”[60]

Formalism, now clearly a derogatory label, became widespread in the Soviet public discourse in the context of a vociferous anti-formalist campaign in 1936, which was opened by two editorials in *Pravda* condemning “formalist perversions” in the music of Shostakovich.[61] His experiments with complex musical language, often unfamiliar and alien to a wide audience, were publicly castigated for their “anti-popular” character. “A formalist” became a common label for anyone detached from life and the needs of the people.

The new meaning of *formalism* loomed large in the attacks Trofim Lysenko and his followers launched against Soviet geneticists in the late 1930s. Accusing geneticists of reducing their work to “formal” statistical analysis, the Lysenkoites put into circulation the label “formal genetics.” In 1936–37 several articles harshly criticized “formalism” in Soviet genetics.[62] Soon this term began penetrating official discourse. The Presidium of the Soviet Academy of Sciences used the term *formal genetics* in its official resolution in May of 1938.[63] In 1939 Stalin’s chief of secret police, Lavrentii Beria, wrote to the foreign minister, Viacheslav Molotov, about “the bourgeois school of so-called formal geneticists.”[64] In 1940, in an attempt to discredit the use of mathematical methods in biology, the philosopher Ernest Kolman unearthed some “incriminating evidence” of the direct connection between “formal genetics” and Hilbert’s mathematical formalism.[65] In a 1930 article, Hilbert drew parallels between genetics and geometry and argued that “the laws of heredity appear as an application of the linear axiom of congruence of the elementary geometrical propositions about plotting the intercepts.”[66] Quoting this passage, Kolman charged that Hilbert had “utterly simplified” and reduced to “meaninglessness” the biological concept of heredity.[67] The ideological label *formalism*, like a floating signifier, passed from mathematics to philosophy to music to biology and back to mathematics, and from academic disputes to Party documents and back to academic disputes.

Formalism resurfaced in official discourse soon after the war. The February 1948 resolution of the Party Central Committee "On the Opera *Great Friendship* by V. Muradeli" condemned "formalist perversions" in Soviet music. The chief ideologist, Andrei Zhdanov, defined formalism as "a rejection of the classical heritage under the banner of innovation, a rejection of the idea of the popular origin of music, and of service to the people, in order to gratify the individualistic emotions of a small group of select aesthetes." He condemned "the formalist trend" in music as "ugly and false, permeated with idealist sentiment, alien to the broad masses of the people, and created not for the millions of Soviet people."[68]

Lysenko's infamous triumph over Soviet geneticists at the July-August 1948 session of the Academy of Agricultural Sciences further popularized the label *formal genetics*. A vociferous campaign against "reactionary" scientific theories followed, quickly spreading Lysenko's style of argument to other disciplines. By analogy with *formal genetics*, the opponents of the structural method in linguistics labeled this approach *formal linguistics*.[69] In structural chemistry, the charge of formalism was leveled against the proponents of the resonance theory.[70] Critics accused some astronomers of formalism and "astronomical idealism" for engaging in research far removed from the practical needs of industrial construction, and a prominent ethnographer was labeled a formalist for placing more emphasis on cultural forms than on social content.[71] *Formalism* became a traveling label, a floating signifier, that could be stuck wherever logical or mathematical reasoning appeared in the sciences. *Formalism* not only traveled across disciplines; most important, it tied together different layers of discourse (scientific, philosophical, and political), effectively erasing boundaries between them. By speaking of formalism, one could easily link mathematical reasoning in science with philosophical mistakes and eventually with political errors. The charge of formalism became one of the basic discursive patterns, or motifs, of newspeak.

From Formulas to "Formalism" in Mathematics

Stalin evidently did not consider mathematics a particularly appropriate subject for ideological critique. When he received a draft of Trofim

Lysenko's 1948 speech, which stated that "any science is class-oriented by its very nature" (i.e., that science must be either "bourgeois" or "proletarian"), Stalin underlined that phrase and wrote in the margin: "Ha-Ha-Ha! And what about mathematics? And what about Darwinism?"[72] The sarcastic tone of this comment suggests that, in Stalin's view, the idea of applying class-based analysis to mathematics was laughable. Yet Soviet mathematicians had little reason to laugh. Stalin's marginal remark remained private, while the vociferous campaigns against "idealism" and "formalism" went on publicly across all scientific disciplines. Some campaign activists managed to find ideological heresy where Stalin himself could not find it: in mathematics.

Taking advantage of the ongoing ideological campaigns, some mathematicians quickly translated their intellectual and institutional conflicts into newspeak. For example, in the summer of 1948 Konstantin Ermilin, a professor of mathematics at Leningrad State University, sent a letter of denunciation to the Party Central Committee. Accusing Soviet specialists in set-theory topology and the algebra of associative systems of using "fancy terminology," of giving "arbitrary definitions" to mathematical objects, and of studying them with a "formal apparatus," Ermilin labeled this a "decadent trend." He argued that such theories emphasized only the "surface, formal side" of mathematics, did not reflect the material world, and were therefore "idealistic." "Pure knowledge," Ermilin declared, could only lead to "total ignorance." "Mathematics is not an entertainment for the devotees of logical constructions," he told Party officials. "One cannot easily accept the fact that the mental energy of highly qualified people is wasted on leisurely play with concepts, while this country is awaiting effective practical help from these people." In conclusion, Ermilin called for mathematical research institutions and university curricula to be purged of the "decadent influences."[73]

Party authorities trusted an investigation to the Leningrad University Party organization, which announced a public discussion of the ideological situation in mathematics. The prominent Leningrad mathematician Aleksandr Aleksandrov realized that Ermilin's letter was motivated by personal intrigues rather than by deep conceptual disagreement. According to the rules of the game, however, the charge formulated in newspeak had to be answered in newspeak. Therefore, Aleksandrov, like Ermilin, assumed the role of an uncompromising fighter against "formalism" and "idealism" in mathematics, but he located these evils elsewhere. Later Aleksandrov recalled: "The next morning I brought to the Party bureau my theses on formalism in mathematics. I seized the stand first and thereby set the direction for the whole discussion. We harshly criticized formalism, but found no formalists in Soviet mathematics, not to speak of our university mathematics."[74] Contrary to Ermilin's expectations, the affair did not result in any disciplinary action. Aleksandrov's rendition of "formalism in mathematics" as a phenomenon characteristic of Western and not of Soviet mathematics successfully diverted the discussion away from personal attacks on his colleagues.

Aleksandrov achieved his goal by applying the familiar "de-ideologization" strategy, which he further developed in a series of articles in the popular magazine *Priroda* [*Nature*] in the early 1950s. In these publications, he drew a sharp line between the "objective content" and the "philosophical interpretation" of scientific theories. He also claimed that the content of scientific knowledge was "independent from the social system or ideology"; it was only the general cultural meaning of scientific ideas that bore an "imprint of society's ideology."[75] The same mathematical theory, Aleksandrov argued, would receive different philosophical interpretations in different ideological contexts. He admitted that mathematics was in a deep ideological crisis in bourgeois societies. In particular, he condemned Hilbert's formalism and Brouwer's intuitionism as philosophical speculations based on "the separation of mathematics from material reality, from practice."[76] He explained that, in their search for the foundations of mathematics, the formalists relied on logical consistency and the intuitionists on the mathematician's personal intuition. Soviet mathematicians, in contrast, were armed with the postulates of dialectical materialism, verified mathematical truths with practice, and were thus protected from philosophical errors. Therefore, while "idealistic perversions" led to the crisis of mathematics in bourgeois societies, Soviet mathematics was ideologically safe. "In a socialist society, a crisis of science is impossible," Aleksandrov declared, "since Marxism—the ideology of socialism—is a scientific ideology and therefore, by its own nature, must be in harmony with the objective content of science."[77] He concluded that, despite the idealistic philosophical interpretations of mathematical logic in the West, Soviet mathematicians should further develop the "objective content" of formal mathematical logic and formal calculi, since without formal logical consistency mathematical theories would lose their power as instruments of science.[78]

In his 1950 review of the philosopher Leonid Maistrov's dissertation "The Struggle of Materialism against Idealism in the Theory of Probabilities," the mathematician Aleksei Liapunov employed a similar discursive technique. Imitating Lysenko, Maistrov discovered two opposite ideological trends in probability theory: a materialistic trend and an idealistic one. He labeled Émile Borel, Richard von Mises, Karl Pearson, and Henri Poincaré "bourgeois scientists." In particular, he argued that, in the statistical interpretation of probability offered by von Mises, probabilities resulted "not from the objective internal characteristics of phenomena but from our experimentation." Maistrov also condemned the attempts to apply probability theory to sociology as a dangerous effort to substitute probabilistic laws for the "real regularities" of social development. "By perverting the theory of probabilities in an idealistic fashion, the educated lackeys of the capital are trying to vindicate the incurable vices of the capitalist society and justify reactionary political theories," he argued.[79] In his review, Liapunov attempted to rescue Western work on probability theory by separating this work from the philosophical views of Western scientists. He covered his ideological bases by declaring his support for Maistrov's negative evaluation of the philosophical and political views of the aforementioned "bourgeois scientists." "I believe, however," Liapunov added, effectively neutralizing the ideological critique, "that it is necessary to emphasize that the main scientific activity of Poincaré, Borel, and von Mises in essence contradicts their own philosophical views."[80]

Various authors drew the line between "scientific activity" and "philosophical views" differently. In her introduction to the Russian edition of Hilbert and Ackermann's *Principles of Theoretical Logic*, Sof'ia Ianovskaia attempted to distance mathematical logic per se from the "idealists parasitizing on mathematical logic." Her critics, led by Maistrov, refused to draw a line between knowledge and ideology, and argued that "the reactionary philosophical views of the founders of bourgeois mathematical logic have perverted the content of this discipline."[81]

By blurring the line between scientific and philosophical terminology, newspeak provided rhetorical resources for both sides in this debate. Militant critics identified mathematical formalism with the philosophical error of "formalism." Drawing heavily on the Marxist principle of practice as the criterion of truth, they associated abstract mathematical reasoning with the "detachment from practice." Their opponents identified abstract thought not with formalism but with generalization (a positive member of the tetrad) and cited Lenin to argue that practice, which always deals with the concrete, can never serve as the final criterion for verifying general knowledge.[82] When particular mathematical theories came under ideological attack, their defenders resorted to the same flexible techniques of newspeak as the critics, shifting the imaginary boundary between knowledge and ideology and providing alternative philosophical interpretations of controversial theories.

From Literary Form to "Formalism" in Linguistics

Linguistics, like any other scientific discipline, was subjected to ideological scrutiny in the search for "formalists" and "idealists" in the course of the ideological campaigns of late Stalinism. The situation was exacerbated by the fact that in linguistics, as in mathematics, *formalism* had a technical meaning, and a number of linguists and literary critics called themselves "the Formalists," thereby directly inviting ideological criticism.

The Formalist movement comprised two distinct groups: the Society for the Study of Poetic Language (Opojaz), founded in 1916 in Petrograd (later Leningrad and now St. Petersburg), and the Moscow Linguistic Circle, founded in 1915.[83] The Opojaz members were primarily literary critics who modeled literary analysis on linguistic studies; the Muscovites were largely professional linguists interested in expanding the scope of linguistic analysis to literary texts. Both groups adopted the view of language as a formal system of signs developed by the Swiss linguist Ferdinand de Saussure. Opposed both to symbolist analysis and to sociological criticism, the Formalists aspired to create "scientific" methods of literary analysis. Their analysis focused on formal artistic devices and textual techniques; they viewed the ideological, psychological, and sociological dimensions of literature as secondary. "A literary work is pure form," declared Viktor Shklovskii, the leader of Opojaz. "It is not a thing or an object; it is a relationship between objects."[84] "If literary history wants to become a science," proclaimed Roman Jakobson (one of the founders of the Moscow Linguistic Circle), "it must recognize the artistic device as its only concern."[85]

In the early Soviet years, the radical stance taken by the Formalist movement met sharp criticism from various sides. Its former supporter Viktor

Zhirmunskii, for example, attacked the Formalists for their exclusive reliance on a single analytical method. "For some adherents of this new trend," he wrote, "the Formalist method becomes the only legitimate scientific theory, not merely a method, but a full-fledged world view, which I would prefer to call formalistic rather than formal."[86] The Formalists' opposition to sociological analysis also prompted a reprimand from Marxist scholars; Leon Trotsky, in particular, condemned "the superficiality and reactionary character" of the Formalist theory. This criticism, however, remained largely academic; even Trotsky admitted that Formalists' work, despite their errors, was still "useful."[87]

In the 1920s the linguistic branch of the Formalist movement produced a major innovation in phonological studies. Jakobson and the prominent linguist Prince Nikolai Trubetskoi emigrated from the Soviet Union to Czechoslovakia, where they became the core of the Prague Linguistic Circle. The Prague school defined phonemes both functionally (as sound elements which differentiate between morphemes) and structurally (as elements in a phonological system). The sound side of language was thus presented as a structural whole rather than a chaotic assembly of individual phonemes. The organization of phonemes into a system with a strictly defined set of relations led Jakobson to the idea of implicational laws (rules) of phonology, which made it possible to predict unknown structural elements on the basis of knowledge of the available elements.[88]

Jakobson aspired to extend the structural approach beyond phonology to the whole of linguistics and eventually to other disciplines. In his view, structural linguistics was part of a larger structuralist trend dominating contemporary science:

> Were we to comprise the leading idea of present-day science in its most various manifestations, we could hardly find a more appropriate designation than *structuralism*. Any set of phenomena examined by contemporary science is treated not as a mechanical agglomeration but as a structural whole, and the basic task is to reveal the inner, whether static or developmental, laws of this system.[89]

After moving to the United States in the 1940s, Jakobson co-founded the New York Linguistic Circle, which further propagated structuralist ideas. With the rise of the Cold War hysteria, however, he became a victim of an anti-Communist "witch hunt." Some of Jakobson's colleagues resented his active contacts with scholars from Eastern Europe and accused him of Communist sympathies. One activist even demanded that Jakobson be "registered as a foreign agent because of the sympathies for the Marxian ideology in his writings."[90] On the other side of the Atlantic, ironically, the same Cold War discourse made him an equally suspect figure in the eyes of ideological watchdogs among Soviet linguists.

In the course of the postwar campaigns against "cosmopolitanism," "kowtowing before the West," and "reactionary and idealistic" Western science, the Formalists and the structural linguists became targets of severe ideological criticism. Jakobson's "faults"—his emigration to the West and his "cosmopolitan" (i.e., Jewish) origins—threw a long dark shadow over his work on structural linguistics, which became almost synonymous with "bourgeois linguistics." The Formalist movement was now closely identified with the philosophical and ideological errors of "formalism" and "idealism." One critic accused Jakobson of reducing "the essence of [linguistic] phenomena to a system of formal oppositions" and branded his views "idealistic."[91] This critic further argued that the Moscow Linguistic Circle had represented a "pillar of formalism, a reactionary bourgeois trend, which attempted to poison the mind of the Soviet intelligentsia." "It is characteristic," this critic continued, "that Jakobson has currently retreated to the USA—a bastion of bourgeois reaction, the principal source of imperialist aggression."[92] The Formalist movement in literary criticism and the structural approach in linguistics were painted as mortal enemies of Marxism, their intellectual flaws closely intertwined with political errors:

> Structuralism is one of the most reactionary trends in modern bourgeois linguistics. This militant formalist doctrine is mobilized completely for the struggle against Marxism in linguistic science and embodies the basic features of bourgeois cosmopolitanism. . . . The theoretical and organizational formation of structuralism in linguistics is inextricably connected with the names of the typical bourgeois cosmopolitan scholars Roman Jakobson and Prince Trubetskoi, people who relinquished their motherland.[93]

As a healthy alternative to this "relic of bourgeois ideology," the critic praised the "new doctrine of language" of the late Marxist linguist Nikolai Marr and extolled the concept of the "dialectical unity of language and thought." This "unity," of course, was not amenable to any formal representation.[94]

Jumping on the bandwagon of the campaign against "reactionary and idealistic" Western science, ideological vigilantes among the linguists rushed to expose in public the "alien" trends in linguistics. Marr's followers, in particular, launched a frontal attack on their main opponents, specialists in comparative historical linguistics and structuralists, carefully couching their critique in ideological terms.[95] Closely adhering to Lysenko's rhetorical style at the July-August 1948 session of the Academy of Agricultural Sciences, campaign activists put Marr on a pedestal as the Russian founding father of genuine linguistics and contrasted his "materialistic" views with "idealistic" and "metaphysical" linguistic theories. Their desire to imitate Lysenko, who had referred to "two trends in biology," was so strong that the leading Marrist critic Fedot Filin entitled a 1948 talk "On Two Trends in Linguistics," even though Marrism and its two main "enemies," comparative historical linguistics and structuralism, made up *three* trends.[96]

Referring to structural linguistic studies in the West, the Marrists quickly labeled them "bourgeois phonology" and accused Soviet structuralists of pursuing "a general formalistic approach to language." Since structuralism and comparative historical linguistics were lumped together as a single "idealistic" trend in linguistics, the charge of formalism was soon extended from one to the other. The Marrists branded the efforts to trace the origins of Indo-European language to the parent Proto-Indo-European language in comparative historical linguistics a "formal-genetic" approach to the study of language, echoing Lysenko's favorite label "formal genetics." The Marrists then could not decide whether it would be better to accuse their opponents of "the identification of thought with language" or "the detachment of thought from language"; in the end, they brought both accusations and concluded that either error led to "pure formalism." To make it clear that ideological errors had be corrected with administrative measures, Filin listed the most important positions occupied by his opponents, implying that those positions would be better filled with Marrists.[97] As a result of these attacks, several prominent specialists in comparative historical linguistics lost their jobs, and one died from a heart attack after two weeks of incessant public castigation.[98]

In June of 1950, with yet another turn of the ideological screw, Stalin suddenly distanced himself from the "excesses" of policies he had previously promoted.[99] In a lengthy article on linguistics in *Pravda*, he branded the Marrist "new doctrine of language" as "truly idealistic" and restored the legitimacy of comparative historical linguistics. Moreover, he condemned the practice of administrative pressure (the "Arakcheev regime"[100]) in science, rejected the idea that one school could hold a monopoly on truth, and called for "freedom of criticism." Stalin's authoritarian call for freedom, however, produced precisely the opposite: comparative historical linguistics immediately assumed monopoly status, the comparativists were again elevated to high positions, and large-scale administrative persecution of the former Marrists began.

Distributed in millions of copies and prescribed for obligatory "discussion" in all academic institutions, "Stalin's doctrine of language" was quickly canonized, along with all its accidental blunders (including Stalin's claim that the hitherto unknown "Kursko-Orlovskii dialect" was the basis of the Russian language[101]). To say that Stalin's sudden about-face came as a shock to the Marrists would be an understatement. Two of them reportedly went mad.[102] Others quickly "reeducated themselves" and began to write prolifically on the imaginary Kursko-Orlovskii dialect. The endless public praise of Stalin's "linguistic genius" was mocked in an underground song:

Comrade Stalin, you're a truly great savant,
By your knowledge of linguistics I am stunned.
I'm a humble Soviet inmate with no roots
And no comrades but gray wolves in the woods.[103]

Stalin evidently enjoyed his role as a great scholar, for he even took time to answer some of the questions sent to him by his readers. One reader asked the "linguistic genius" to clarify the meaning of the traveling label *formalism*, indiscriminately used by the Marrists: "Many linguists consider *formalism* one of the main reasons for stagnation in Soviet linguistics. It would be very desirable to know your opinion, what is formalism in linguistics and how to overcome it?"[104] Stalin, a true expert in newspeak, patiently explained the political function of this floating signifier in linguistics:

> N. Ia. Marr and his "disciples" accuse of "formalism" all linguists who do not support the "new doctrine" of N. Ia. Marr. This is, of course, preposterous and mindless. N. Ia. Marr considered grammar a simple "formality" and called "formalists" those who viewed the grammatical structure as the foundation of language. This is altogether silly. I think that "formalism" was invented by the authors of the "new doctrine" to facilitate the struggle against their opponents in linguistics.[105]

By that time, the label *formalism* had become so pervasive in Soviet academic discourse that even Stalin's explicit critique could not put an end to the wanderings of this empty signifier. Traditional historical comparative linguists, who had taken the place of Marrists as the officially approved linguistic school, often similarly translated their intellectual disagreement with the structuralists into ideological terms. Traditional linguists studied phonemes in isolation from one another, while structuralists attempted to arrange the phonemes into a unified system and measure their characteristics. Comparative linguists branded such efforts formalistic. "The structural approach is not a method of linguistic research," one critic argued, "but merely a technique of formal mathematical representation of the results of research, and this form of representation does not add any new knowledge of language."[106] In politically charged academic debates, the use of mathematical formulas in the social sciences and the life sciences almost invariably provoked the allegation of formalism.

The Specter of "Idealism" in Physiology

Under the banner of the struggle against "formalism," the Lysenkoites expelled mathematics from Soviet biology, while the Marrists and the comparativists barred it from Soviet linguistics. Physiology remained one of the very few disciplines in which one could still expect mathematical formalisms to play a legitimate role. After all, it was Ivan Pavlov himself, the icon of Soviet physiology, who proclaimed in the early 1910s that "the edge of physiological knowledge, its true goal is to express the infinitely complex relationship between the organism and its environment in a precise mathematical formula." "This," Pavlov continued, "is the ultimate goal of physiology, this is its frontier."[107] Pavlovian experiments on conditioning always involved precise quantitative measurements. In his programmatic 1902 address "Natural Science and the Brain," Pavlov expressed confidence that even human thought would eventually lend itself to mathematical description:

> All life—from the most elementary to the most complex organisms, including, of course, the human beings—is a long chain of more and more complex, up the highest degree, balances with the environment. The time will come—maybe in the distant future—when mathematical analysis based on natural-scientific research will embrace with magnificent formulas of equations all these balances, eventually including itself.[108]

Ivan Petrovich Pavlov (1849–1936) occupied an exceptional place in Soviet science, both as a man and as a symbol.[109] Named the "leading physiologist of the world" at the Fifteenth International Psychological Congress in 1935, he enjoyed great international fame. Before World War II, he was the only Nobel Laureate among Soviet scientists, and thus he was a valuable national asset in both scientific and propaganda terms. To advance his ambitious agenda of experimental and theoretical research, Pavlov made use of his administrative authority as the head of several laboratories and his personal access to Soviet leaders as an expert advisor to the government. After his death in 1936, his theory of conditional reflexes became a canonical conceptual framework for Soviet physiology.

For Pavlov, modern technology was an emblem of sophistication and he aspired to "elevate" his theory of nervous activity to an equally high level of complexity. Accordingly, his laboratory at the Institute of Experimental Medicine in St. Petersburg was organized as a giant "physiology factory," with rigid division of labor, strict discipline, uniform experimental procedures, and checking of knowledge claims to make sure that they conformed to the Pavlovian theoretical framework.[110] Pavlov strove to uncover precise quantitative laws governing physiological processes. He insisted on the "complete exclusion of psychic influence" from his experiments, so that machine-like regularities underlying the functioning of physiological mechanisms would not be obscured. Viewing the organism as a complex machine, Pavlov modeled his ideal of scientific investigation after engineering practice:

> Man is definitely a system (more crudely speaking, a machine), which, like any other system in nature, obeys the inescapable and uniform laws of all nature; but this system, in the horizon of our contemporary scientific view, is unique in its highest degree of self-regulation. Among the products of man's hands, we are already sufficiently familiar with machines that regulate themselves in various ways. From this point of view, the method of studying the man-system is the same as for any other system: decomposing into parts, studying the role of each part, studying the connections among the parts, studying the relations with the environment, and finally, based on all this, understanding the overall functioning of this system and, if within human capacity, controlling it.[111]

In his writings, Pavlov constantly borrowed metaphors from contemporary technology; for example, he called the digestive system a "chemical factory."[112] His central metaphor—the human nervous system as a central telephone switchboard—illuminated the crucial distinction between unconditional and conditional reflexes.[113] According to Pavlov, inborn unconditional reflexes fixedly tied a particular stimulus (e.g., the viewing of food) to a specific response (e.g., salivation). Pavlov compared such reflexes to a set of direct, permanent telephone lines. Conditional reflexes (e.g., salivation in response to the ringing of a bell, previously associated with the viewing of food) could be acquired, lost, and reestablished. Pavlov likened conditional reflexes to flexible temporary connections between telephone users through a switchboard. “In technology, as in our daily life,” he wrote, “the principle of [temporary] connection is applied so often that it would be odd not to expect the implementation of the same principle in the mechanism of the higher nervous system, which establishes most complex, subtle connections.”[114] In the same way as the central telephone station solved the problem of communication for a large number of users, the mechanism of conditional reflexes, in Pavlov’s view, solved the problem of the organism’s reaction to diverse stimuli.

In the early Soviet years, new machines, such as tractors and electric generators, were hailed as signs of progress and emblems of the bright communist future. Man-machine metaphors permeated public discourse. Poetry and popular songs propagated images of “iron men” with “a flaming engine in place of heart.” The Soviet fascination with Taylorism and Fordism produced a popular movement for the “scientific organization of labor” led by Aleksei Gastev, a visionary who saw increasing mechanization and standardization of workers’ movements, language, and even thoughts as means of improving the efficiency of labor. In 1920 Gastev organized the Central Institute of Labor in Moscow and launched a wide range of scientific studies and training courses. [115] In 1922 Gastev hired the physiologist Nikolai Aleksandrovich Bernshtein (1896–1966), who would later play the leading role in Soviet “physiological cybernetics.”

Throughout his career, Bernshtein spoke openly and consistently about his disagreement with Pavlov’s doctrine of conditional reflexes, even when it became an official dogma.[116] Pavlov’s experiments focused principally on the correlation between a dog’s salivary gland activity and various stimuli; he dealt neither with locomotion nor with human experimental subjects. Bernshtein studied precisely what Pavlov left out: human motor activity. In the early 1920s, Bernshtein conducted a series of experiments at the Institute of Labor, measuring the trajectories and speeds of human limbs, while his subjects performed such tasks as hammering, typing, or playing piano. He further developed and refined experimental techniques of the European science of “biomechanics,” which conceptualized the human body as a mechanical system of muscular masses and forces.[117] Classical neurophysiology assumed that each muscle had a singular representation in the corresponding area of the brain; a central impulse from a given area was thought to direct a determined movement of the corresponding muscle. Bernshtein called this "the push-button control-board model of the cortex, similar in plan to an organ keyboard."[118] In contrast, his experiments showed that the same labor task was performed differently—with varying tensions of different muscles—at various times. Muscular movements were "constructed" anew, so to speak, each time the task was performed.[119] Bernshtein argued that reflex theory could not explain muscular movements, and he interpreted locomotion not as a sequence of pre-determined actions (as in the Pavlovian reflex theory) but as a cycle of actions and corrections. As early as 1934, Bernshtein proposed to replace the classical Pavlovian concept of the "reflex arc" with a "reflex circle."[120]

After the establishment of Pavlov's reflex theory as an unquestionable physiological canon, all alternatives to the Pavlovian doctrine quickly disappeared from academic discourse. When the "patriotic" campaign of the late 1940s prompted the search for Russian-born "founding fathers" in all scientific disciplines, physiologists did not have to search very hard. Pavlov was already recognized as the leader of their discipline, and the only question was who would benefit from the closest association with Pavlov's name. Like many other canons, the Pavlovian legacy proved amenable to diverse interpretations. Some of Pavlov's former students laid exclusive claims to his legacy and began to pull Soviet physiology in different directions. An institutional conflict between rival groups within the physiological community took the form of a debate over the correct interpretation of Pavlov's teaching.

In accordance with the political style of the day, this debate was conducted in newspeak. Some of the "Pavlovians" cleverly linked Pavlov's teaching to the newly canonized doctrine, Lysenko's theory of the inheritance of acquired characteristics. They disregarded the well-known fact that Pavlov had supported Soviet geneticists in the 1930s and had even ordered that a monument to Gregor Mendel be erected in front of his laboratory. Instead, they "creatively" reinterpreted the scientific legacy of their late mentor and claimed its full compatibility with Lysenkoism. They revived Pavlov's early hypothesis (which he later rejected) about the inheritance of conditional reflexes and their transformation into unconditional ones, and they portrayed this hypothesis as the central dogma of the Pavlovian doctrine. In June and July of 1950, with the blessing of Party authorities, they convened a special joint session of the Academy of Sciences and the Academy of

Medical Sciences in Moscow to solidify their reinterpretation of Pavlov's teaching and to purge their opponents.[121] Several prominent physiologists who resisted this dogmatic interpretation of Pavlov's teaching were accused of the "perversion of Pavlov's line" and dismissed from their jobs. Pavlov's most talented disciple, Leon Orbeli, who did not support the myth of "Pavlov the Michurinist," was relieved of his administrative positions in Soviet physiology, and this opened wonderful career opportunities for orthodox Pavlovians. The name Pavlov now stood for Party-blessed dogma in science. The rejection of such a dogma amounted to a political mistake.

Bernshtein, who disagreed with Pavlov conceptually and did not even attempt to portray himself as an orthodox Pavlovian, became a prominent target of ideological criticism. The onset of the anti-Semitic campaign against "cosmopolitanism" made Bernshtein, a Jew, particularly vulnerable. Despite his highly acclaimed wartime work on the restoration of damaged motor functions at the Moscow Scientific Research Institute of Prosthetics and the 1947 awarding of the prestigious Stalin Prize for his book *On the Construction of Movements*, Bernshtein was subjected to severe public criticism. His critics pointed out that he had mentioned Pavlov's name in his book only once and accused him of attempting to "belittle" Pavlov's significance. Furthermore, since Bernshtein cited foreign authors, he was charged with "kowtowing before foreign scientists" and "anti-patriotism."[122] The critics also attached to Bernshtein's doctrine the usual labels: *idealism* (for using mathematical analysis) and *mechanicism* (for regarding the human body as a self-regulating mechanism). They even accused him of holding onto the "false theory of mutations" (i.e., genetics). At the 1950 "Pavlov session," critics alleged that he knew "neither the letter nor the spirit of Pavlov's teachings." Such criticism amounted to political denunciation, and Bernshtein was soon forced out of his job and lost any opportunity for research and publication.[123]

Instead of exploring the intellectual differences between Pavlov's doctrine and Bernshtein's approach, the critics simply followed the clichés of newspeak and portrayed the conflict between Pavlov and Bernshtein as a clash between dialectical materialism and an alien philosophy of science. Ironically, they "discovered" ideological heresy in precisely those aspects of Bernshtein's work that were, if anything, dialectical and materialist. If Bernshtein's extensive use of mathematical analysis was "idealistic," why was Pavlov's call for "magnificent formulas of equations" not idealistic? If

Bernshtein's flexible circular mechanism of physiological regulation was mechanistic, what should Pavlov's crude telephone-switchboard model of the nervous system be called?

Under the banner of the campaign against "reactionary and idealistic science," the critics systematically translated Pavlov's teaching into positive ideologemes and Bernshtein's doctrine into negative ones. The critics did not even notice that they had accused Bernshtein of deviating from dialectical materialism in two opposite directions—idealistic and mechanistic—at the same time. The charges of "idealism" and of "mechanicism" belonged to the same discursive strategy of "criticizing and destroying" the scientific opponent as an ideological enemy. As ideological synonyms, idealism and mechanicism were interchangeable, despite their opposite descriptive meanings.

Like any ideological language, scientific newspeak did not recognize inner contradictions. The same theory could be translated into newspeak in many different ways, and Soviet scientists took full advantage of this opportunity to produce alternative translations. The main ideological question in postwar Soviet science was not whether or not to be a dialectical materialist. The question was whose claim to being a dialectical materialist would be officially recognized.

In this chapter I have attempted to analyze postwar academic discourse not as a container of a particular ideology but as a mechanism for formulating and advancing political and research agendas in the language of newspeak. Instead of postulating a cleavage between "science" and "ideology," I have explored the common language spoken by both scientists and ideologues. Newspeak did not express any pre-existing ideological system; instead, it functioned as a surrogate ideology. By fusing description with evaluation, newspeak fulfilled the main function of ideology: it provided a framework for value judgments.[124] One can hardly derive diverse and eclectic newspeak practices from some fixed ideological principles. Quite the opposite: Soviet ideology itself may be more productively viewed as the result of conscious attempts to explicate and rationalize assorted discursive strategies, or mechanisms, of newspeak, in much the same way as grammatical rules are invented to describe diverse linguistic practices.[125]

While the meaning of "Soviet ideology" varied widely, the Soviet ideological discourse seems to have followed very specific patterns and rules.

No individual controlled it: as we have seen, the Stalinist view of mathematics as an ideology-laden field was not necessarily Stalin's own view. Stalin could condemn a particular use of the label *formalism* in linguistics, but he could not stop its spread into other fields. Discursive inertia carried "floating signifiers" from one area to another. Newspeak had a life of its own. Both the rulers and the ruled were similarly caught up, as Mikhail Heller has put it, "in the magical circle" of the Soviet language: "There are no augurs in the Soviet logocracy who, using the Word as a weapon, can protect themselves from its influence. Everybody lives and works within the bounds of the Soviet vocabulary and of the Soviet patterns of thought."[126]

When Sof'ia Ianovskaia faced ideological criticism of her role in the publication of the Russian translation of Hilbert and Ackermann's *Principles of Theoretical Logic*, she immediately performed the ritual of "self-criticism" and published a repentant letter, admitting "idealistic confusion" in her work. To vindicate herself, she now had to show some effort at "criticizing and destroying" ideological heresy in her field. A learned student of Marxism, she quickly dug up a passage in *Anti-Dühring* in which Engels ridiculed the analogy between the calculating machine and the human mind. Fitting Engels into the ongoing campaign against idealism in science, Ianovskaia wrote that his critique had been "aimed against the reactionary ambitions of idealism . . . to substitute [human] reasoning with computing." Having thoroughly "criticized and destroyed" this idealistic error, Ianovskaia successfully fulfilled her ideological obligations. She then turned quietly to rescuing the "scientific meaning" of Hilbert and Ackermann's work by emphasizing its importance for "technicians working on the construction of calculating-solving machines and automata."[127] Using the "de-ideologization" strategy, she drew a sharp line between the objective content of mathematical logic and its "idealistic" philosophical interpretation.

While the "overtake and surpass" attitude dominated in Soviet physics and the "criticize and destroy" trend triumphed in biology, the field of computing, or "machine mathematics," was an intriguing borderline case. The first electronic digital computers were built in Britain and the United States in the 1940s and the early 1950s as direct products of military-sponsored research and became vital components of weapons systems. The popular perception of computers in the West was largely shaped by cybernetics' man-machine analogies: computers were seen as "giant brains," while human behavior was often interpreted within the framework of calculation, manipulation, and control. Together, the military importance of computing and the ideological ramifications of cybernetic metaphors created an ambiguous and complex situation for Soviet computer specialists.

I will discuss Soviet attitudes toward American cybernetics and explore the interplay of the "overtake and surpass" and "criticize and destroy" motifs in the early history of Soviet computing in chapter 3. Before examining the Soviet case, however, it is appropriate to explicate the fundamentals of cybernetics. In chapter 2, I will discuss major cybernetic ideas developed by American and Western European scientists and engineers in the 1940s, viewing the diverse and eclectic analogies between the human brain and the computer, between human communication and information exchange, and between negative entropy and biological and social order through the prism of a shared metaphorical language that I call *cyberspeak*.

2

Cyberspeak: A Universal Language for Men and Machines

Recently, two facts have entered to change the situation. On the one hand, devices have been built that (so it is said) are more like men than the old machines were. Modern computers can be programmed to act unpredictably and adaptively in complex situations. That is, they are intelligent. On the other hand, men have behaved in ways that (so it is said) correspond rather well to our old ideas about mechanisms. They can be manipulated, "brain washed" and apparently controlled without limit. With this sharp increase in the number of properties that men and machines seem to have in common, the analogy between them becomes more compelling.

—Ulric Neisser, "Computers as Tools and Metaphors" (1966)[1]

In November of 1959 the magazine *Science* published a jocular article titled "Report of the Special Committee." Its author lamented the fact that special advisory committees on important scientific and technological problems were spending too much time and effort in preparation of their final reports, and suggested a radical simplification of this whole process. He observed that such reports always used the same arguments and ended with the same conclusion: an urgent request for more funding. Therefore, it would be expedient to abolish such committees altogether and instead utilize a ready-made "standard, universal form" already including all the clichés that distinguished an efficient, well-thought-out report:

Summary Report of Special Committee On X

1. This is a scientific field of critical importance, with obvious and widely ramified interconnection with national defense and with the health of our national economy. The intellectual and esthetic importance of deepening our knowledge in this area cannot be overemphasized.
2. This field has been meagerly supported in the past, and there is every reason to expect that modest but suitable financial support (say, roughly 20 times the present level) could lead promptly to results of the highest significance.
3. . . . the present moment [is] a particularly fortunate and promising one for undertaking an energetic attack.

4. . . . [the experts] have developed a momentum which is a great present asset, but which might decay rapidly if encouragement is not promptly supplied.
5. Your Committee deeply deplores—indeed condemns—international rivalries in science. But we nevertheless feel compelled to point out that the Russians appear to be, in this field X, well ahead of us.
6. Your Committee thus recommends the immediate creation of a National Institute on X . . . together with a broad program of research funds, fellowships, travel grants, and so on.[2]

One only needed to replace X with "a word or phrase suitable to the special case in hand" (for example, "the design and construction of a much larger, faster, and more flexible computer"), and a perfect committee report would be completely ready.

American scientists returning to civilian research after working on wartime defense projects sought ways to apply new techniques they had developed during the war to a wide range of problems, and, incidentally, to extend the generous funding they had received during the war to the postwar period. They argued that methods they had developed for solving specific military problems (for example, tracking airplanes and enciphering messages) had general theoretical significance and could solve numerous communication and control problems far beyond the military realm. This argument became a recurrent theme in innumerable proposals showered on funding agencies after the war by American scientists and engineers. The jocular "universal form" merely reflected this trend of unrestrained expansion of the new methods and theoretical models "in all suitable institutions," "throughout the waters of the oceans of this planet," "within the deep core of the earth," "in the arctic and antarctic areas," "throughout the troposphere," and "in space."[3]

One field of study seemed particularly well suited for this "universal form," for it had truly universal aspirations to explain "all human behavior." From wartime efforts to build computers and feedback devices for control and communication, a set of techniques of formal logical representation, mathematical modeling, and computer simulation of purposeful behavior had emerged. A number of American and British scientists and engineers from various fields had compared the human brain to the electronic digital computer both structurally and functionally, and had drawn parallels between thinking and computation, between human memory and computer storage, and between the all-or-none principle of neuron "firing" and the binary mathematics of digital computers. More generally, they had come to view negative feedback (used in such devices as servomechanisms and computers) as the fundamental mechanism of self-regulation in human physiology and in society. Patterns of military control and communication became models for a wide range of human activities. The American mathematician Norbert Wiener introduced these ideas to a broad audience in his 1948 book *Cybernetics, or Control and Communication in the Animal and the Machine*.[4] A new "universal" language, which I call *cyberspeak*, tied together a diverse set of man-machine metaphors. Living organisms, control and communication devices, and human society were now described in the same terms: *information*, *feedback*, and *control*.

It was hardly a coincidence that the "Summary Report of Special Committee On X" was written by an active promoter of cybernetic ideas. The author was Warren Weaver, director of the Alfred P. Sloan Foundation and of the Natural Science Division of the Rockefeller Foundation, chairman of the Basic Research Group of the Department of Defense, trustee of the Sloan-Kettering Institute, and member of National Science Foundation—an outstanding science administrator widely regarded as "the dean of American Science."[5] It was at the request of Weaver, then the chief of the Applied Mathematics Panel of the National Defense Research Committee (NDRC), that the mathematician John von Neumann drafted his famous report on the first electronic digital computers, in the spring of 1945. In the autumn of 1940 Weaver (then the head of NDRC section D-2, a fire-control division) let a contract for "General Mathematical Theory of Prediction and Applications," carried out by Wiener and the electrical engineer Julian Bigelow. A year later, Weaver let another contract for Wiener to write up his theoretical results in a report, titled The Extrapolation, Interpolation, and Smoothing of Stationary Time Series, that lay a mathematical foundation for cybernetics. After the war, Weaver, through the Rockefeller Foundation, actively supported Wiener's early studies in cybernetics. In 1940 Weaver also let a contract to the communications engineer Claude Shannon for "Mathematical Studies Relating to Fire Control," under which Shannon studied the problem of improving the smoothness of tracking. In parallel, Shannon worked at the Bell Telephone Laboratories on designing a speech-encipherment system under a top-secret cryptological project whose code name, "Project X," was later echoed in Weaver's jocular "Summary Report on X." This project contributed much to Shannon's "mathematical theory of communication," later generalized as "information theory"—one of the central components of cybernetics. And it was Weaver who in 1949 publicly promoted information theory as a suitable explanatory framework for "all human behavior."

Cybernetics was a very peculiar historical phenomenon. It could not be classified as a conventional scientific discipline, as an engineering approach, or as a philosophical doctrine, though it resembled each somewhat. The cybernetic mixing of humans and machines produced very diverse sociopolitical and cultural ramifications, and attitudes toward cybernetics were equally varied. A number of recent historical studies have traced the origins of major cybernetic concepts to Wiener's work on anti-aircraft gun control during World War II and have argued that cybernetics embodied distinct military patterns of control and communication. In particular, Peter Galison has suggested that cybernetics, operations research, and game theory formed a set of "Manichean sciences" that made military conflict a model for human interaction with the world.[6] Andy Pickering has traced the role of the World War II "regime" in the emergence of a whole range of "cyborg objects" (such as computers and anti-aircraft gunnery, with its "coupling of men and artillery") and "cyborg sciences" (including cybernetics and operations research).[7] Paul Edwards has argued that American cybernetics bore the distinctive cultural imprint of the Cold War and that the language of cybernetics became a vehicle of Cold War discourse. The cultural imagery of computers, or the "cyborg discourse," embodied in integrated human-machine systems and artificial intelligence devices, was closely linked to the "closed-world discourse," which reflected the ideological stereotypes of the Cold War. Reified in military command-and-control systems, the two discourses intertwined to form a vision of the political and social world as a closed, computable system subject to manipulation and control.[8]

David Mindell, in contrast, emphasizes that Wiener began working on the general principles of cybernetics only after his anti-aircraft predictor project had been canceled, and that cybernetics became for Wiener a civilian enterprise in the midst of World War II. Mindell argues that "cybernetics recast military control in a civilian mold"[9] and sees the roots of cybernetics in the prewar traditions of control engineering and communication engineering, which widely employed the metaphor of intelligent behavior for servomechanisms and the analogy between the nervous system and a telephone network.

Different faces of cybernetics are reflected in the personalities of two major contributors to cybernetics: Wiener and von Neumann. Steve Heims has sharply contrasted Wiener, a "New Englander with a social conscience," with von Neumann, a "hard-boiled, weapons-minded 'realist.'"[10] David Noble has similarly emphasized that the two men had very different views of the social implications of cybernetic ideas:

> Unlike John von Neumann, whose mathematical axiomatic approach reflected his affinity for military authority and control, Wiener insisted upon the indeterminacy of systems and a statistical, probabilistic understanding of their functioning. Any technical part of social systems, he stressed, should be designed to complement, to be compatible with, and therefore to sustain and enhance human life. Overly determined systems, in delimiting the full range of human thought and action, would tend toward instability and breakdown because they narrowed down the range of negative feedback: self-adjusting, self-correcting action. . . . Wiener wanted to ensure that advances in technology would benefit labor, not industrial corporations.[11]

Wiener's liberal social outlook and pacifist ideas paradoxically combined in the cybernetic discourse with von Neumann's cold rationalism and militaristic attitude. This discourse thus became permeated with tension and ambiguity and opened up to various interpretations.

Cybernetics seems difficult to pin down to a single political or social trend. While some view it as an extension of military patterns of thinking and behavior into the civilian realm, others see it as a liberating movement that destroys traditional cultural divisions and stereotypes. For example, Donna Haraway has argued that humans are in fact becoming "cyborgs"—cybernetic organisms, or hybrids of machine and organism—and that cybernetics effectively undermines the rigid "dichotomies between mind and body, animal and human, organism and machine, public and private, nature and culture, men and women, [and] primitive and civilized."[12]

In this chapter, instead of looking for a single interpretation of cybernetic ideas, I focus on the emergence and cultural ramifications of the language of cybernetics. In my view, the diversity of meanings ascribed to cybernetic ideas owes much to the flexibility of this "universal" language. Cybernetics is viewed here as a product of juxtaposition of diverse disciplinary and cultural discourses characteristic of postwar American science. To place American cybernetics in a larger international context, I start by comparing the research trajectories of two great mathematicians, Norbert Wiener and Andrei Kolmogorov—trajectories that initially closely paralleled each other but suddenly diverged precisely at the birth of cybernetics.

Norbert Wiener and Andrei Kolmogorov: Two Mathematicians Tackle Biology

Norbert Wiener was a prodigy. He read at age 3, enrolled in high school at 9, entered Tufts College at 11, and graduated at 14.[13] Andrei Kolmogorov also showed his talents very early. At age 5 he edited the mathematical section of a homemade magazine, inventing mathematical problems and curiosities for each issue. At 14 he taught himself higher mathematics by reading an encyclopedia and, upon entering Moscow University, quickly passed exams for the freshman year and moved up to sophomore status, thus obtaining a food ration privilege—vitally important in the post-revolution years.[14]

Kolmogorov started as a mathematics student but soon developed a strong interest in the humanities. At Moscow University he studied with the prominent historian Sergei Bakhrushin and, at age 17, wrote a meticulously researched paper based on a statistical analysis of tax records in medieval Russia. Bakhrushin praised the paper but did not recommend it for publication. "You have found only one proof," he explained to young Kolmogorov. "That is very little for a historian. You need at least five proofs."[15] At that moment, as Kolmogorov would later tell his students, he decided to concentrate in mathematics, where one proof would suffice.

Wiener also majored in mathematics, but he too showed diverse interests in other fields, trying first biology and then philosophy. He enrolled in the doctoral program in philosophy at Harvard University and, at age 18, completed a dissertation in mathematical logic. He then went to Cambridge University to study symbolic logic with Bertrand Russell. Kolmogorov too became interested in mathematical logic—particularly the contemporary controversy over intuitionism, a logical theory that challenged the transfinite applications of the *tertium non datur* principle (the law of the excluded middle) in classical logic. In 1925 he published a seminal article in which he "embedded" classical logic in intuitionist logic, thus showing that all finite conclusions of classical logic could be proved without transfinite application of the *tertium non datur* principle.

Kolmogorov quickly attained international fame among mathematicians. In 1923, at age 19, while still an undergraduate at Moscow University, he made a fundamental contribution to the theory of functions. He constructed an odd, counterintuitive mathematical object—a summable function whose

Figure 2.1
Norbert Wiener in Moscow, 1960. Courtesy of Natal'ia Liapunova.

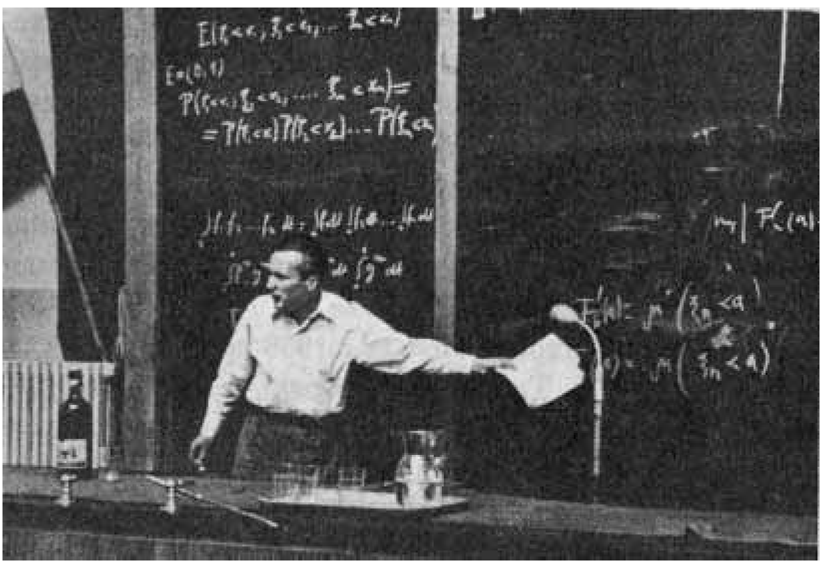

Figure 2.2
Andrei Kolmogorov at a Mathematics Congress in Hungary, 1950. From Shiriaev, ed., *Kolmogorov v vospominaniiakh*.

Fourier series diverged almost everywhere. In 1931 Kolmogorov was appointed professor of mathematics at Moscow University, where he taught until his death in 1987. Wiener, who taught mathematics at the Massachusetts Institute of Technology from 1919 until his retirement in 1960, first became famous for his 1920–1923 studies of Brownian motion. Each Brownian particle moves in an unpredictable zigzagging trajectory and the space of such trajectories has an infinite number of dimensions; Wiener provided a statistical description of this process by assigning probabilities to subsets of such trajectories. This measure of probabilities for infinite-dimensional spaces became known as *Wiener measure*. The theory of stochastic processes emerged from Wiener's work, and Kolmogorov became one of the leading researchers in that field. In 1933 he co-authored an important article on Brownian motion. Soon after that, Kolmogorov reformulated the foundations of the theory of probability in terms of measure theory, producing his famous system of axioms for probability theory (a system now considered standard).

Kolmogorov and Wiener were intensely aware of each other's work. Wiener later recalled: "Khintchine and Kolmogoroff, the two chief Russian exponents of the theory of probability, have long been involved in the same field in which I was working. For more than twenty years, we have been on one another's heels; either they had proved a theorem which I was about to prove, or I had been ahead of them by the narrowest of margins."[16] While visiting Moscow in the summer of 1960, Wiener told an interviewer: "When I read works of Academician Kolmogorov, I feel that these are my thoughts as well, this is what I wanted to say. And I know that Academician Kolmogorov has the same feeling when reading my works."[17]

The race between Kolmogorov and Wiener took a particularly dramatic turn during their parallel work on prediction theory. In a series of articles published in 1939, 1940, and 1941, Kolmogorov developed a theory of interpolation and extrapolation of stationary sequences.[18] Wiener reportedly learned of Kolmogorov's work in late 1941, when he was working on similar problems.[19] In February of 1942 Wiener submitted a classified report for the military on extrapolation, interpolation, and smoothing of stationary time series.[20] Kolmogorov derived his theory from purely theoretical studies of the geometry of Hilbert spaces, whereas Wiener arrived at this topic while working on the problem of predicting the trajectories of enemy aircraft, but their results, by Wiener's admission, "turned out to be equivalent."[21] While Kolmogorov was more rigorous in his theoretical formulations, Wiener developed an application-oriented theory of filtration, which provided a convenient basis for solving engineering problems.[22]

In the 1930s, both Wiener and Kolmogorov developed an acute interest in the applications of mathematics to biology. Wiener took an active part in the Philosophy of Science Club, an interdisciplinary seminar on scientific method led by the prominent physiologist Walter Cannon at the Harvard Medical School. This seminar, attended largely by medical scientists, focused on the attempts to solve the mind-brain relationship with newest neurological methods, including brain wave encephalography. Kolmogorov applied various mathematical methods to the problems of evolutionary biology and genetics. In particular, he studied traveling waves associated with the spread of an advantageous gene in a linear habitat and concluded, almost simultaneously with and independently from R. A. Fischer, that the range inhabited by individuals with favorable characteristics would expand with an asymptotically constant velocity. This model laid the foundation of a general mathematical theory of reaction-diffusion that would later serve to describe the spread of epidemics, rumors, advertising, and cultural innovations. Kolmogorov's involvement with biological problems, however, proved short-lived.

In 1940 Kolmogorov entered a scholarly dispute over the use of statistical methods in genetics, which quickly turned into an ideological controversy. In 1939 the Soviet journal *Vernalization*, a mouthpiece of the supporters of the notorious hack scientist Trofim Lysenko, published a paper by a graduate student named Ermolaeva, who claimed to have empirically refuted the famous Law of Segregation of Gregor Mendel's classical genetics. She had replicated the basic monohybrid cross experiment, which, theoretically, was to result in the 3:1 split of traits in the second generation, with one-fourth of the offspring displaying the recessive trait and three-fourths displaying the dominant trait. Ermolaeva found certain deviations from the 3:1 ratio and concluded that Mendelian genetics did not withstand the test of statistical experiment. Soviet geneticists approached Kolmogorov, and he wrote a brief rebuttal, explaining that the small size of Ermolaeva's statistical sample accounted for this discrepancy and that her data in fact amounted to "a new brilliant confirmation of Mendel's laws."[23]

The Lysenkoites immediately redirected their ideological attacks at Kolmogorov. If statistics did not become their ally, it had to be treated as an enemy. In his published reply to Kolmogorov, Lysenko equated the use of probability theory and statistics in biology with the submission to "blind chance": "We biologists . . . do not want to submit to blind chance, even though this chance is mathematically admissible," he wrote. "As a biologist, I am not interested in the question whether or not Mendel was a good mathematician. As to my opinion of Mendel's statistics," he continued, "I claim that they have no bearing whatever on biology. . . . [Kolmogorov's] article, too, has no bearing whatever on biological science."[24] In short, if statistics did not confirm the dogmas of Lysenkoism, it was not applicable to biology. The philosopher Ernest Kolman labeled Kolmogorov's mathematical treatment of genetics a philosophical heresy. Kolman argued that, by deriving biological conclusions from his mathematical analysis, Kolmogorov had committed a serious methodological error:

> Unfortunately, . . . instead of confining himself to the purely mathematical aspect of the matter, [Kolmogorov] draws conclusions which go beyond the limits of mathematics, and declares himself in favor of Mendel and Morgan's genetics. . . . If Mendel's law is a biological law, it cannot be proved or disproved by mathematical or statistical means. Only on the basis of biology . . . can Mendel's law be proved or disproved as a universal biological law. . . . Mendel's law of segregating factors deduced from a definite group of cases of inheritance is nothing but a statistical rule, and not a universal biological law. . . . Statistics as applied to biology must occupy a subordinate place.[25]

Threatened with the prospect of involvement in a dangerous philosophical and ideological debate, Kolmogorov was forced into a defensive position and had to reassure the critics that he had spoken only of the statistical "confirmation" of Mendel's law, not of its "proof."[26]

This incident put an abrupt end to Kolmogorov's inroads into biology. To avoid ideological complications, for many years he limited the applications of his mathematical techniques to physical problems and stayed away from the life sciences and the social sciences, urging his students to do the same.[27]

During World War II, both Wiener and Kolmogorov joined the war effort. Under a contract with the NDRC, Wiener worked on the problems of anti-aircraft gun control. From the results of his prediction theory, Wiener elaborated a statistical model that maximized the probability of a successful hit. With the engineer Julian Bigelow, he designed and built an "anti-aircraft predictor," a device for predicting the trajectory of an enemy plane. Wiener suspected that Kolmogorov was following a similar path; he even asked Vannevar Bush, director of the US Office of Scientific Research and Development, for permission to collaborate with Kolmogorov. Even though the Soviet Union was then viewed as an ally of the United States, this permission evidently never came.[28]

Kolmogorov was indeed following a parallel path, working on problems of ballistics and also using a statistical approach, although he focused on ground artillery rather than anti-aircraft fire and applied a different mathematical apparatus. He elaborated the general principles of evaluating the effectiveness of artillery fire on the basis of target-destruction probability, and he estimated the conditions under which artificially induced dispersion of combat shells would be efficient.[29] Years later these principles would be employed by the designers of Soviet anti-aircraft and anti-missile defense systems.[30] For his wartime work, Kolmogorov was twice awarded the Order of Lenin, the highest mark of honor in the Soviet Union. Wiener's results in prediction theory would later also prove very important for weapons design; however, his anti-aircraft predictor did not work very well, and in January of 1943 his wartime project was terminated.[31] At this point, the paths of Wiener and Kolmogorov began to diverge.

Control via Feedback: The Body as a Servomechanism

While Kolmogorov made mathematical applications in the life sciences a taboo, Wiener chose precisely this subject for his new research project. Upon returning to civilian research, Wiener switched his interests to neurophysiology. He decided to use some of the insights gained during his wartime work to explain neurophysiological mechanisms of human behavior.

Wiener's work on the anti-aircraft predictor led him to a far-reaching analogy between the operation of servomechanisms (feedback-based control devices) and human purposeful behavior. This predictor was designed to forecast the future trajectory of an enemy airplane and to help point a gun at the position where the airplane and a shell would meet. This function was usually performed by human gun pointers and gun trainers, and Wiener's device would therefore "usurp a specifically human function." Wiener described the actions of human gunners in mathematical terms "in order to incorporate them mathematically into the machines they control," and he came to view his anti-aircraft predictor as an engineering model of human behavior in this situation. In order to test the predictor, Wiener and Bigelow had to generate a set of trajectories of the enemy aircraft, and they used servomechanisms to simulate these trajectories. They assumed that "an aviator under the strain of combat conditions is scarcely in a mood to engage in any very complicated and untrammeled voluntary behavior."[32] The enemy pilot's evasion technique, they concluded, would follow the same feedback principle that was implemented in servomechanisms. Wiener and Bigelow then extended this analogy to the anti-aircraft gunner and began thinking of the role of feedback in a broader range of human activities.[33]

After the termination of the anti-aircraft predictor project, Wiener and Bigelow teamed up with the Mexican physiologist Arturo Rosenblueth, whom Wiener had met at a session of the Philosophy of Science Club, to explore the implications of the servomechanism analogy. They concluded that human voluntary activity was based on "circular processes, emerging from the nervous system into the muscles, and re-entering the nervous system through the sense organs."[34] They attributed various pathological conditions in which a simple voluntary act such as picking up a pencil would lead to uncontrollable oscillations to breaking of this circular mechanism. Wiener, Rosenblueth, and Bigelow came to view this circularity as a universal principle of purposeful behavior. They called it *feedback*, borrowing the term from control engineering. They interpreted any goal-directed action—from pointing a gun to picking up a pencil—as a negative feedback process in which the attempts to approach the goal were constantly corrected by return signals from the goal that indicated the current distance from its (anticipated) position, or "the amount by which we have failed to pick up the pencil at each instant."[35]

In 1943 Wiener, Rosenblueth, and Bigelow published a joint article, in which they suggested that purposeful human behavior was governed by the same feedback mechanism that was employed in servomechanisms.[36] Combining terms from control engineering (*feedback*), psychology (*purpose*), philosophy (*teleology*), and mathematics (*extrapolation*), they constructed a classificatory scheme of behavior that was equally applicable to human action and machine operation (figure 2.3).

Both human activity and machine operation could be purposeful, if the feedback principle was involved. By showing how organisms and machines could achieve their goals by means of the deterministic feedback mechanism, Wiener, Rosenblueth, and Bigelow undermined the philosophical oppositions between teleology and determinism, between voluntary acts and mechanical actions, and ultimately between men and machines. They

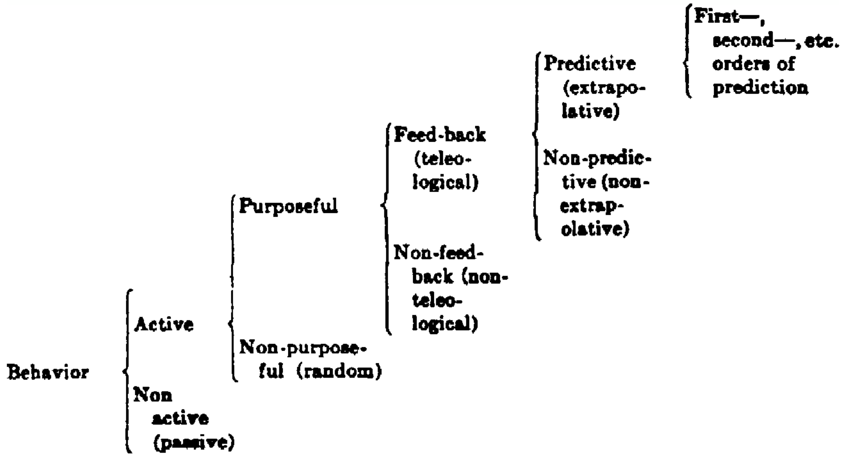

Figure 2.3
The classification of behavior. From Rosenblueth, Wiener, and Bigelow, "Behavior, Purpose and Teleology."

argued that "the broad classes of behavior are the same in machines and in living organisms."[37] Therefore, they argued, organisms and machines could be described in similar terms and studied with the same methods.

Several years later, Wiener attempted to show that the feedback mechanism would explain such widely recognized neurophysiological phenomena as Pavlovian conditional reflexes. He introduced the notion of *affective tone*, which, "arranged on some sort of scale from negative 'pain' to positive 'pleasure,'" would make it possible to reinforce favorable reactions:

> An increase in affective tone favors all processes in a nervous system that are under way at the time and gives them a secondary power to increase affective tone; and . . . a decrease in affective tone tends to inhibit all processes under way at the time and gives them a secondary ability to decrease affective tone. . . . Note that the mechanism of affective tone is itself a feedback mechanism.[38]

Wiener then drew a direct analogy between reflexes and anti-aircraft fire control. In both cases, he argued, "anticipatory feedback" was involved, which included an effector with a lagging characteristic and a compensator that acted as a predictor. "Feedbacks of this general type are certainly found in human and animal reflexes," he wrote. "Any system of anti-aircraft fire control must meet the same problem."[39]

Wiener's formulation of the problem of prediction and control—in living organisms as well as in machines—in the mathematical terms of statistical mechanics raised some fundamental physical and philosophical questions. One of these questions concerned the paradoxical ability of living organisms to develop and sustain a high degree of organization, the ability that stood in apparent contradiction to some basic physical laws.

The Order of Life: The Organism as an Entropy-Reducing Machine

The second law of thermodynamics—"nature's tendency to degrade the organized and to destroy the meaningful," as Wiener put it[40]—posed a serious obstacle for any attempt to provide a statistical description of living processes. The Austrian theoretical physicist Erwin Schrödinger directly confronted the problem of paradoxical stability and even increasing complexity of living organisms, which apparently disobeyed the "natural tendency of things to approach the chaotic state"—"the same tendency," he remarked, "that the books of a library or the piles of papers and manuscripts on a writing desk display."[41] Schrödinger's 1944 book *What Is Life?* served as an important source for Wiener's attempts to find a universal basis for order and control in living and non-living nature.

The topic of Schrödinger's book was somewhat unusual for a physicist.[42] In the introduction, Schrödinger referred to some "difficulties of language" he had experienced. Although he may have meant that his English needed polishing, he also faced linguistic difficulties of a different kind. Schrödinger aspired to give a physical account of biological phenomena—that is, to explain them by physical and chemical laws. He decided to abandon the language of mathematics, the "physicist's most dreaded weapon," because his subject seemed "much too involved to be fully accessible to mathematics."[43] Instead, Schrödinger offered a systematic reinterpretation of biological phenomena in physical terms. In other words, he attempted to translate life into the language of physics.

Schrödinger defined life as "orderly and lawful behavior of matter"; however, as he quickly discovered, living matter seemed to violate the accepted physical order and behaved rather unlawfully. He suggested that the thermodynamic concept of entropy be used as a quantitative measure of organization and order in living organisms, and he immediately faced a physical paradox. The living organism—a complex, highly organized system—seemed to disobey the second law of thermodynamics, which prohibited entropy decrease in closed systems. Instead of plunging into entropy/chaos, living organisms demonstrated "admirable regularity and orderliness" and were able to keep up the existing order. Schrödinger formulated the chief problem of life as a strictly physical problem: How were living organisms able to obviate this inescapable tendency toward a "thermal death"? To solve this paradox, he set out to find a physical basis of order in the living cell.

Schrödinger suggested that the stability of life was maintained by a specific mechanism of "order from order." Citing the contemporary chromosome theory of heredity, he found the internal source of order in the organism in extremely stable genetic structures—the chromosome fibers—which he translated into the physical language as "aperiodic crystals." Schrödinger argued that these "incredibly small groups of atoms, much too small to display exact statistical laws, [played] a dominating role in the very orderly and lawful events within a living organism"[44]: they controlled the development of the organism's features and provided for the transmission of traits from generation to generation. The stability of chromosomes, in turn, was supposedly maintained by the constant influx of order in the form of highly ordered organic molecules contained in food. Schrödinger interpreted the organism as a thermodynamic system that counteracted the inevitable increase of entropy by absorbing "negative entropy," or "drinking orderliness," from the environment.

Paradoxically, the root of life was found in the clockwork-type, mechanical principle of "order from order." "We seem to arrive at the ridiculous conclusion that the clue to the understanding of life is that it is based on a pure mechanism,"[45] Schrödinger admitted. The fundamental divide thus lay not between living organisms and machines but between order and chaos. Both organisms and machines fought chaos with order, and by similar means: "order from order."

ORGANISMS AND MACHINES	**vs.**	**NATURE**
order	vs.	chaos
control	vs.	statistical laws
influx of negative entropy	vs.	increasing entropy
organization	vs.	disorganization

Figure 2.4
Adapted from Schrödinger, *What Is Life?*

The emerging parallels between genetics and quantum physics fascinated Schrödinger, one of the founders of quantum mechanics. "The significant fact [of genetic mutations] is the discontinuity," he wrote. "It reminds a physicist of quantum theory—no intermediate energies occurring between two neighboring energy levels. He would be inclined to call [Hugo] de Vries's mutation theory, figuratively, the quantum theory of biology. We shall see later that this is much more than figurative. The mutations are actually due to quantum jumps in the gene molecule."[46] Schrödinger borrowed this interpretation of genetic mutations as physical events from the 1935 joint article of the Russian geneticist Nikolai Timoféeff-Ressovsky, the German biologist Karl Zimmer, and the German (later American) physicist Max Delbrück. They calculated the rate of x-ray-induced genetic mutations as a function of the dose, and they estimated the target area for mutation-inducing ionization. Schrödinger, unaware at the time that many of the claims made in this article had later been revised, assumed that this estimate indicated "the size of the gene." The biochemist Max Perutz later soberly concluded that "what was true in [Schrödinger's] book was not original, and most of what was original was known not to be true even when the book was written."[47]

Despite its technical blunders, Schrödinger's book proved extremely significant in its conceptual impact: it rendered the biological problem of life as a physical problem of molecular order that could be addressed with the help of physical methods, theories, and instruments. This book played a major role in what Evelyn Fox Keller has called a "political and cognitive synergy" of physics and biology—a synergy that resulted in the emergence of molecular biology.[48] Molecular biology became an attractive alternative for those physicists who were dissatisfied with the military engagement of nuclear physics. Under the influence of Schrödinger's book, a number of young scientists—including James Watson, Francis Crick, Maurice Wilkins, and Seymour Belzer—began applying physical methods to biology. Schrödinger's translation of biological concepts into the language of physics allowed molecular biologists to borrow their research agenda, their attitudes, their techniques, and eventually their social authority from physics. At the same time, the physical-biological language Schrödinger forged made it possible to channel biological analogies into the realm of machines and vice versa. His terminology became one of the main components of the language of cybernetics.

Schrödinger introduced into scientific discourse the central metaphor of molecular biology: the chromosome as a message written in code.[49] He called the chromosome fiber a "hereditary code-script," an "architect's plan" for a future organism. Using a social metaphor, he also compared chromosomes to "stations of local government dispersed through the body, communicating with each other with great ease, thanks to the code that is common to all of them."[50] The code metaphor seemed particularly appropriate in a wartime cultural context filled with allusions to code making and code breaking. At that very moment, across the Atlantic, the communication engineer Claude Shannon was working on cryptological problems and applying the same code metaphor to human communication. Like Schrödinger, Shannon borrowed the notion of entropy from thermodynamics and used it in a broader sense. Schrödinger's conceptual framework differed from Shannon's in two important respects: Schrödinger interpreted codes as instruments of control, while Shannon viewed them as tools of communication; and Schrödinger interpreted entropy as a measure of disorder, while Shannon used it as a measure of uncertainty. On the basis of shared metaphors, however, biophysicists and communication engineers began to find a common language: cyberspeak.

Human Communication as an Engineering Problem: Man as an "Information Source"

One of the crucial steps in the formation of cybernetics was made when major problems in control engineering and in communication engineering were reformulated in the mathematical terms of statistical mechanics and reinterpreted as problems of filtering and prediction. During World War II, Wiener worked simultaneously on two projects: the construction of an antiaircraft predictor and the design of wave filters to eliminate background noise in electrical networks. He quickly realized that smoothing a rough curve to predict the future aircraft trajectory was akin to filtering out high-frequency oscillations from electrical signals. It proved impossible, however, to construct an ideal prediction mechanism. An apparatus designed to achieve high precision on very smooth curves turned out to be very sensitive and was sent into oscillation by the smallest departure from smoothness. To balance the contradictory demands of smoothness and stability, Wiener elaborated statistical means of analysis of the signal and the noise, thus laying a mathematical foundation for the design of both the anti-aircraft predictor and the wave filters. Wiener and his collaborators became convinced that "the problems of control engineering and of communication engineering were inseparable."[51] The same conclusion was reached at about the same time by a group of control and communication engineers at the Bell Laboratories. Working under defense contracts from the NDRC, they compared the central problem of anti-aircraft fire control—tracking the trajectory of an enemy airplane—with the standard communication engineering problem of filtering out noise. They found "an obvious analogy between the problem of smoothing the data to eliminate or reduce the effect of tracking errors and the problem of separating a signal from interfering noise in communications systems."[52] Out of this juncture of control engineering and communication engineering emerged the idea of unity of control and communication—one of the theoretical underpinnings of cybernetics.

Bell Labs engineers formulated the mathematical problems of anti-aircraft fire control—data smoothing and prediction—in terms of communication engineering as "a special case of the transmission, manipulation, and utilization of intelligence."[53] Engineers used such terms as *intelligence*, *information*, and *communication* in narrow technical senses. Ironically, these strictly technical terms would later be used widely to describe in "precise terms" the cultural phenomena to which they initially referred only in a metaphorical sense.

In 1924 Harry Nyquist, an engineer working for the American Telephone and Telegraph Corporation, referred to the rate of sending of a signal as "the speed of transmission of intelligence."[54] He proposed to measure this speed as the logarithm of the number of possible "values" to be transmitted (the number of different characters, in case of telegraphy). In 1928 the Bell Labs engineer Ralph Hartley replaced the anthropomorphic term *intelligence* with the more neutral *information*, which he proposed to measure as the logarithm of the number of possible messages, or symbol sequences of a specified length.[55] In his article "Transmission of Information," Hartley suggested this logarithmic function as a common "quantitative measure whereby the capacities of various systems to transmit information may be compared."[56] By introducing bandwidth as a common measure of information capacity, Nyquist and Hartley together provided a unified framework for analyzing transmission of various types of signals: radio waves, telegraph messages, telephone voice signals, television images. This universal mathematical description of diverse communication technologies laid the foundation for a unified theory of communication. As David Mindell has argued, this theoretical synthesis reflected corporate goals: AT&T capitalized on communication theory to advance its claim of a natural monopoly over all media. AT&T portrayed its efforts to become the unified communications company controlling telephony, telegraphy, radio broadcasting, and television as a necessary means for providing "substantially instantaneous transfer of intelligence" throughout the United States.[57]

Man-machine metaphors are double-edged: while describing machines in anthropomorphic terms, one often conceptualizes humans in machine-like terms. In 1935 the Bell Labs engineer Homer Dudley patented the Vocoder, a device that extracted the amplitudes of a speech signal at ten different frequencies, transmitted them separately, and then reconstructed the speech signal at the receiving end. Dudley viewed his device as a model of human communication. "Communication by speech consists in sending by one mind and the receiving by another of a succession of phonetic symbols with some emotional content added," he wrote. Dudley compared human speech to "a radio wave in that information is transmitted," and effectively blurred the distinction between human communication and transmission of radio signals—both were merely regarded as transfer of information.[58] During World War II, on the basis of the Vocoder, Bell Labs engineers designed the "X-system," which added a digital "key" to each speech component and served to provide secure top-level communication between Washington and London.[59] This project, known as "Project X," helped establish a crucial link between communication engineering and cryptology.

Claude Shannon, a communication engineer at Bell Labs, participated both in the fire-control project and in "Project X," and his work tied the problems of communication engineering, control engineering, and cryptology together. Later he recalled: "The work on both the mathematical theory of communications and the cryptology went forward concurrently from about 1941. I worked on both of them together and I had some of the ideas while working on the other. I wouldn't say one came before the other—they were so close together you couldn't separate them."[60] Shannon's conceptualization of the central problems in communication engineering (the accurate and efficient transmission of signals) and in cryptology (the accurate and efficient coding and decoding of messages) began to converge and resulted in the emergence of information theory.[61]

Like Wiener, who faced the contradictory demands of smoothness and stability for his anti-aircraft predictor, Shannon tried to balance two contradictory requirements of accuracy and efficiency of communication. For greater efficiency, signals had to be shorter; for greater accuracy and elimination of possible errors resulting from noise, signals had to be "redundant" (that is, longer). To balance the two criteria, Shannon introduced a quantitative measure that allowed him to evaluate both the degree of distortion by noise and the efficiency of encoding. Following Hartley, Shannon called this measure *information*. Shannon proposed to measure information in *bits* (binary digits), a term first suggested by John W. Tukey, a Princeton mathematician who also worked on fire-control problems during the war and who joined Bell Labs in 1945. One bit stood for an elementary choice between two equally probable alternatives; the choice from among four possibilities could be split into two elementary binary choices and thus required two bits of information; and so on. As Hartley had shown, the information required to choose one message from a set of equally probable messages amounted to the logarithm of the number of messages. Shannon considered a more general case in which different messages could occur with different probabilities. Shannon's formula for information in this case proved identical to that of entropy in statistical mechanics, and he suggested calling it the "entropy of the information source," measured in bits per symbol. Shannon proved a "fundamental theorem" which asserted that, by efficient encoding, one could transmit information at a rate arbitrarily close to the channel capacity when measured in bits per second. In his view, the notions of information, entropy, and certainty were closely intertwined: information measured the final certainty resulting from the decoding of a message, while entropy measured (the equal amount of) initial uncertainty before decoding the message. Shannon used the terms *entropy* and *uncertainty* interchangeably.[62]

After the war, Shannon published his results on communication engineering and on cryptology in two separate articles, using essentially the same conceptual framework.[63] In the first article, he subsumed various forms of communication under the universal scheme of a "general communication system," which used the same generic names for both human and machine components:

(1) the *information source,* which produces a message or sequence or messages to be communicated to the receiving terminal;
(2) the *transmitter,* which operates on the message in some way to produce a signal suitable for transmission over the channel;

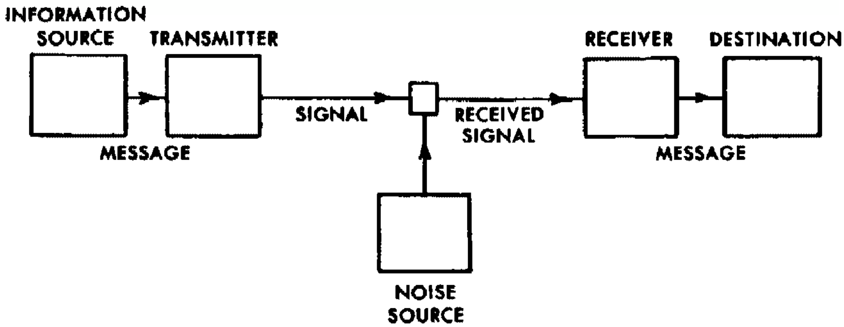

Figure 2.5
Schematic diagram of a general communication system. From Shannon and Weaver, *The Mathematical Theory of Communication.*

(3) the *channel* is merely the medium used to transmit the signal from the transmitter to receiver;
(4) the *receiver* ordinarily performs the inverse operation of that done by the transmitter, reconstructing the message from the signal;
(5) the *destination* is the person (or thing) for whom the message is intended.[64]

Other essential elements of the scheme were (6) the *message* itself (written or spoken words, pictures, etc.) selected out of a set of possible messages; (7) the *information*, "a measure of one's freedom of choice when one selects a message"; (8) the *signal*, a sequence of discrete symbols or a continuous function sent over the communication channel; and (9) the *coding process*, which changed the message into the signal.

In "Communication Theory of Secrecy Systems," Shannon translated this scheme into the cryptological language, calling the transmitter the *encoder* and the receiver the *decoder*. In both cases, he interpreted human communication as an exchange of encoded messages. (See figure 2.6.)

Viewing man as an "information source," Shannon not only interpreted human communication as transmission of messages generated with certain probabilities; he also viewed human language itself as a stochastic process. In other words, he interpreted texts in natural language as sequences of individual letters generated with certain probabilities. This was how cryptanalysts had traditionally viewed natural language. One well-known cryptanalytic technique was based on the comparison between the average frequencies of letters in natural-language texts and the observed frequencies of symbols in a given encoded message; in the simplest code, the most frequent symbols would likely correspond to the most frequent letters.

HUMAN COMMUNICATION	COMMUNICATION SYSTEM / SECRECY SYSTEM
addresser	information source
sender	transmitter/encoder
medium	channel
uncertainty	entropy/noise
meaning	information
recipient	receiver/decoder
addressee	destination

Figure 2.6
Adapted from Shannon and Weaver, *The Mathematical Theory of Communication*, and Shannon, "Communication Theory of Secrecy Systems."

Shannon proposed a series of simple artificial languages as approximations to English and argued that "a sufficiently complex stochastic process [would] give a satisfactory representation" of natural language as a discrete source of information.[65]

Shannon's interest in man-machine analogies dated back to his work at MIT in the second half of the 1930s. In his master's thesis, Shannon employed Boolean algebra (a symbolic description of the "laws of thought") to express the functioning of relay switching circuits, thus laying the foundation for the seminal analogy between human thinking and digital computing.

The Computer and the Mind as Universal Logical Machines

The transition from analog to digital computers in the 1940s involved changing not only the technical basis of computing but also its disciplinary affiliation and its cultural connotations.[66] Mathematicians and logicians began to play an important role in the design and programming of computers. Computing could now be described in purely logical terms, independent of its physical implementation. Various mathematical, engineering, and psychological concepts were gradually translated into logical terms, and a new general language of computation emerged. Both the digital computer and the human mind were conceptualized as logical machines. In the next step, the mind came to be seen as a computer.

One of the most powerful analog computers of the day, the Differential Analyzer, was developed at MIT under the direction of Vannevar Bush, and both Norbert Wiener and Claude Shannon had close contacts with Bush's group. While a graduate student, Shannon worked on improving the controls of the Differential Analyzer, which involved a complex digital circuit built of electromechanical relays. In his 1937 master's thesis, Shannon represented on-off relay switches with true-or-false logical propositions of Boolean algebra, thus turning relay circuit design into a logical problem that could be solved by formal means. As the official history of Bell Labs proclaimed, Shannon effectively transformed relay circuit design from "a somewhat esoteric art to . . . a science."[67] From Shannon's work, it became clear that one could build a digital calculating machine using only interconnected relay switches. An important advantage of this approach was that electromechanical relays operated much faster than the cogged wheels traditionally used in mechanical calculating machines, such as Bush's Differential Analyzer. In 1937–38 Bush circulated a proposal to build a "rapid arithmetical machine" based on electronic switching, which eventually reached Howard Aiken, the designer of the first electromechanical digital computer, Mark I.[68]

In the summer of 1940 Wiener came up with his own proposal for building a digital computing machine for the solution of partial differential equations. In a memorandum submitted to Bush, he formulated several main requirements for such a machine: the construction of a numerical central apparatus for addition and multiplication, the use of electronic tubes instead of gears or mechanical relays as switching devices, the adoption of the binary numerical system, the laying out of the entire sequence of logical and mathematical operations on the machine itself, and the construction of an erasable and reusable storage of data. Although Wiener himself did not pursue this computer project, he later realized that these ideas were "of interest in connection with the study of the nervous system."[69]

The concept of a logical machine played a crucial role not only in the first proposals for digital computers but also in the theoretical conceptualization of computation by the British mathematician Alan Turing. He attempted to solve the problem whether mathematics was decidable, that is, whether there existed a definite method to determine if any given mathematical assertion was true. This problem, called the Entscheidungsproblem, was proposed by the German mathematician David Hilbert at the Mathematical Congress in 1928. In his 1936 article "On Computable Numbers," Turing suggested a machine-like logical procedure for imitating any computation performed by a human mathematician. He postulated that "the behavior of the [human] computer at any moment is determined by the symbols which he is observing, and his 'state of mind' at that moment."[70] He compared "a man in the process of computing a real number to a machine which is only capable of a finite number of conditions."[71] Instead of reading off and writing on two-dimensional paper, this abstract logical machine would "scan" a symbol from a one-dimensional tape and then make a "move" along that tape, perhaps erasing this symbol and writing a different one. Turing represented each "state of mind" of the human computer with a particular "configuration" of the machine, which determined which "move" would be made and how the configuration changes if a particular symbol is scanned. Together, the operations performed by this machine and the changes in its configuration constituted its "behavior." Turing further generalized his model by introducing "the universal computing machine," which could read off the tape the description of any other computing machine of this type and then carry out the computations of that machine. Any possible human computation, Turing concluded, could be performed by this "universal computing machine," and therefore the limitations of this machine would indicate the limitations of mathematics in general. In that article, Turing showed that some definable numbers could not be computed by the "universal machine" and thus proved that the Entscheidungsproblem had no solution. One of the steps leading to this negative conclusion eventually proved more culturally significant than the end result: the concept of the "universal computing machine" and the proof of its existence became a powerful positive result of Turing's work.

Shannon's description of the digital computer as a logical machine and Turing's conceptualization of human computation as a logical procedure converged in the unified vision of the computer and the mind as logical machines. In 1943, while visiting Bell Labs, Turing met with Shannon, and they had long conversations. According to Turing's biographer Andrew

Hodges: "Shannon had always been fascinated with the idea that a machine should be able to imitate the brain; he had studied neurology as well as mathematics and logic, and had seen his work on the differential analyzer as a first step towards a thinking machine. [Turing and Shannon] found their outlook to be the same: there was nothing sacred about the brain, and that if a machine could do as well as a brain, then it *would* be thinking."[72] This outlook was soon shared by Wiener, who began speaking of "the computing machine, and consequently the brain, as a logical machine" and calling for logic to be reduced to "the study of the logical machine, whether nervous or mechanical, with all its non-removable limitations and imperfections."[73]

The Logic of the Brain: The Nervous System as a Turing Machine

While Shannon and Turing were making functional comparisons between human thinking and logical computing, the neurophysiologist Warren McCulloch and the logician Walter Pitts were drawing structural analogies between the nervous system and a network of logical elements.

In May of 1942 the Josiah Macy Jr. Foundation sponsored a conference (held in New York) on cerebral inhibition. At this meeting, which focused on hypnosis and on the physiology of the conditional reflex, Arturo Rosenblueth presented the results of his joint studies with Norbert Wiener and Julian Bigelow. Conceptualizing purposeful behavior in engineering terms, they suggested that the human body be viewed as a "black box," and they compared it to a feedback-controlled servomechanism. Among those present was Warren McCulloch (of the University of Illinois Medical School), who was interested precisely in the content of this "black box"—that is, in the neurophysiological mechanisms of human behavior. In collaboration with Walter Pitts (of the University of Chicago), he elaborated a logical model of the brain functioning, which turned out to be remarkably similar to Turing's logical machine.

Trained initially as a philosopher, McCulloch liked big questions.[74] In particular, he aspired to answer the most fundamental epistemological question: "How do we know anything about the world?"[75] In search of the answer, he had turned from philosophy to psychology and then to neurophysiology. His approach, which he called *experimental epistemology*, was to find "a satisfactory explanation of *how we know what we know*, stated in terms of the physics and chemistry, the anatomy and physiology, of the biological system."[76] McCulloch started with the search for "what an atom was to chemistry, or a gene to genetics"—the "simplest psychic act," the most fundamental element, the ultimate building block of mental activity:

> My object, as a psychologist, was to invent a kind of least psychic event, or "psychon," that would have the following properties: First, it was to be so simple an event that is either happened or else it did not happen. Second, it was to happen only if its bound case had happened . . . that is, it was to imply its temporal antecedent. Third, it was to propose this to subsequent psychons. Fourth, these were to be compounded to produce the equivalents of more complicated propositions concerning their antecedents.
>
> In 1929 it dawned on me that these events might be regarded as the all-or-none impulses of neurons, combined by convergence upon the next neuron to yield complexes of propositional events.[77]

Taking the activity of a single neuron as the sought-after "psychon," McCulloch attempted to build a model of mental activity from the bottom up. In 1941, having taken a job in the Department of Psychiatry at the University of Illinois, he came into contact with a small group of researchers in "mathematical biophysics" at the University of Chicago, led by the Russian-born physicist Nicolas Rashevsky. Rashevsky's group aspired to create a systematic mathematical biology modeled after mathematical physics: it would relate to experimental biology as mathematical physics related to experimental physics. Rashevsky focused his research on mathematical modeling of nerve excitation and conduction, but he viewed those merely as electrical phenomena rather than as processes of communication. As Wiener later put it, for Rashevsky's group "the engineering of the body [was] a branch of power engineering."[78] In this group, McCulloch found a kindred soul in Pitts, a young, very talented, self-educated logician. Together they elaborated an entirely different vision of neurophysiological processes. Instead of viewing the brain as an electrical circuit, they conceptualized it as a logical machine.

Inspired by Turing's 1936 paper "On Computable Numbers," McCulloch and Pitts took a purely logical approach to the description of mental activity. In McCulloch's words, they "abstracted from real neurons everything irrelevant"[79] and represented all-or-none neuron impulses as true or false logical propositions. Then they linked these "formal neurons" into networks, which could be represented as functions of propositional logic. "What we thought we were doing (and I think we succeeded fairly well)," McCulloch later recalled, "was treating the brain as a Turing machine."[80]

In 1943 McCulloch and Pitts published a highly influential paper, "A Logical Calculus of the Ideas Immanent in Nervous Activity," in the *Bulletin of Mathematical Biophysics*, which was edited by Rashevsky. Postulating "all-or-none" as a "law of nervous activity," they explored the possibilities it offered. McCulloch and Pitts showed that, under certain assumptions, any network of formal neurons could be represented by a logical function, and that, conversely, for any logical function one could construct a neural net that would produce that function. "The behavior of every net can be described in these [logical] terms, with the addition of more complicated logical means for nets containing circles," they wrote, "[and] for any logical expression satisfying certain conditions, one can find a net behaving in the fashion it describes."[81]

For McCulloch and Pitts, the construction of formal neural networks served only as an auxiliary device in their ultimate quest for "the nervous theory of knowledge."[82] They were concerned with the epistemological implications of their model, rather than its neurophysiological validity. From their point of view, the most significant result of their paper was proving that any particular logical function could be implemented in formal neural networks in many different ways. From that it followed that one could not determine the structure of the neural network unambiguously by observing its output, since "inference from any sample of overt behavior to nervous nets is not unique."[83] Solely by observing the outputs of the "black box," one could not deduce what mental activity was going on inside it.

McCulloch and Pitts interpreted the limitations of their formal model of the brain in philosophical terms as the fundamental limitations on our knowledge of the world. Without knowledge of the structure of the neural network, they argued, it would not be possible to deduce the input to the network (the "facts" about the "external world") from its output (our "perception"), insofar as "if our nets are undefined, our facts are undefined."[84] Furthermore, even if one knew the structure of the network and the current states of all the neurons, one could compute only the succeeding states. The presence of disjunctive relations and/or circular paths in the net would make it impossible to determine all the preceding states. In other words, from the perceptions retrieved from one's memory, it was not possible to deduce the "facts" that caused those perceptions. "Thus our knowledge of the world, including ourselves, is incomplete as to space and indefinite as to time," McCulloch and Pitts concluded.[85] They suggested that our knowledge of the world was fundamentally limited in two ways: (1) From our present activities, we could not gain knowledge of ourselves (i.e., determine our neural net structure). (2) Although we could sometimes predict the future, we could not determine the past.

As a by-product of their analysis of formal neural networks, McCulloch and Pitts proved that such networks could compute any number computable by the Turing machine. This result had no significance for "experimental epistemology"; it could be useful, they thought, only to psychologists. McCulloch and Pitts argued that their analysis of formal networks provided "a psychological justification" for Turing's definition of computability: "If any number can be computed by an organism, it is computable by these definitions, and conversely."[86] Blurring the distinction between the formal neural network and the actual mental activity, McCulloch later argued that "a nervous system can compute any computable number."[87] Even if we cannot know the world, we can at least compute as many numbers as a universal logical machine.

While an undergraduate at Haverford College, McCulloch had been asked about his plans in life. "I have no idea," he replied, "but there is one question I would like to answer: What is a number, that a man may know it, and a man, that he may know a number?"[88] It seems that for McCulloch the question "How do we know anything about the world?" eventually turned into "How do we know a number?" Summing up his 1947 article with Pitts, "How Do We Know Universals," McCulloch wrote that this article "cannot be wrong in its all-important proof that for a man to know such universals as shape regardless of size or chord regardless of key it would be sufficient for his brain to compute enough averages."[89] Having reduced the knowledge of the world to the computability of numbers, McCulloch and Pitts successfully found a common denominator for the epistemology of humans and that of machines. "We had proved, in substance," McCulloch wrote later with evident pride, "the equivalence of all general Turing machines—man-made or begotten."[90]

In 1943, after publishing his article with McCulloch, Pitts went to MIT to study with Wiener, who introduced him to Shannon's work on the logical analysis of switching circuits.[91] At the intersection of McCulloch and

Pitts's logical model of the brain, Turing's logical model of the mind, and Shannon's logical model of digital computing, an integrated vision of the mind and the brain as logical computing machines began to emerge. This vision was most forcefully expressed by the prominent mathematician John von Neumann.

The Computer as a Brain and the Brain as a Computer

It is hard to imagine two people as different as Norbert Wiener and John von Neumann.[92] Wiener was a myopic, absent-minded professor, an armchair scientist, a liberal intellectual with strong ethical convictions, and a vehement pacifist who refused to participate in any US government projects after the bombing of Hiroshima. Von Neumann was an energetic and practical man, a cold-blooded rationalist, an indefatigable traveling consultant, an active contributor to the Manhattan Project, and a member of the Atomic Energy Commission; he knew his way around the Pentagon and the corridors of power. Yet they were very much interested in each other's work, they maintained a "professional friendship,"[93] and they had a productive working relationship that resulted, in particular, in the crystallization, formulation, and mathematical analysis of diverse cybernetic ideas. Although the conceptual trajectories of their thought went in opposite directions (Wiener was "humanizing" machines whereas von Neumann was "rationalizing" humans), their destinations, ironically, were the same. Their views eventually converged on a common set of man-machine metaphors that formed the basis of cyberspeak.

Various uses of formal logical language—by Shannon to describe relay circuits, by Turing to define a universal logical machine for computation, and by McCulloch and Pitts to build a model of the nervous system—linked electrical engineering, computing, and neurophysiology together and provided an opportunity for sharing models, tools, and metaphors among these fields. By describing the operations of the first electronic digital computers in similar logical terms, and comparing them to the human brain, von Neumann added a crucial link to this nexus.

Von Neumann, who had major responsibility for the complex mathematical calculations needed for the Manhattan Project, collaborated closely with the designers of the first electronic digital computer (ENIAC) and its stored-program successor (EDVAC). In the spring of 1945 Warren Weaver, the head of the NDRC Applied Mathematics Panel, asked him to write a report on the current state and the future prospects of computing machines.[94] This report clearly outlined the concept of the stored program and explicated what became known as the "von Neumann architecture" for digital computers. Von Neumann did not describe the stored-program computer in terms of the electromechanical relays or the vacuum tubes used in the computers of his day, however; he employed McCulloch and Pitts's language of idealized neurons. Observing that both the formal neurons and the switching and relay components of computing machines worked on the all-or-none principle (being either on or off, either excited or quiescent), he argued that any digital computing device, natural or artificial, would consist of such logical "elements."

Von Neumann conceptualized the formal neural networks of McCulloch and Pitts as a general model of computation, applicable both to the man-made computers and to the human brain. While McCulloch and Pitts employed a logical formalism to illuminate neurophysiological questions, von Neumann took their neurophysiology to illuminate the logical design of computers. The logical language served to describe both the functioning of vacuum tubes and the human neural activity, and through logic the computer and the brain became inextricably connected. The "neuron analogy," which for von Neumann initially served to separate the principal logical design of computers from its implementation in specific engineering components, would provide a powerful metaphorical framework for computing for years to come.

Von Neumann radically reinterpreted McCulloch and Pitts's 1943 article. He decided that their logical description of "formal neurons" captured the "essential traits" of actual nervous cells. McCulloch and Pitts had merely argued that a formal network of simple all-or-none elements could produce some complex patterns of behavior. Von Neumann concluded that all complex behavior ("anything that you can describe in words") could be ultimately reduced to computation in a formal neuron network:

> It certainly follows that anything that you can describe in words can also be done with the neuron method. And it follows that the nerves need not be supernaturally clever or complicated. In fact, they needn't be quite as clever and complicated as they are in reality, because an object which is a considerably amputated and emasculated neuron, which has many fewer attributes and responds in a much more schematic manner than a neuron, already can do everything you can think up.[95]

Von Neumann argued that "the neurons of the higher animals are definitely elements in the above sense"[96] and proceeded to consider living organisms "as if they were purely digital automata."[97] In other words, von Neumann reinterpreted the logical model of McCulloch and Pitts as an essential description of neural activity and then projected this description onto computers, suggesting a "neural model" for computing.

In von Neumann's interpretation, the correspondence between the formal neural network and the abstract logical computer (the Turing machine), which McCulloch and Pitts established as a "psychological" by-product of their epistemological study, became the crux of the whole matter. Von Neumann argued that the main result of McCulloch and Pitts's article was that "the generality of neural systems is exactly the same as the generality of logics."[98] Linking their work with a similar result obtained by Turing for abstract computing machines, von Neumann built a chain of direct analogies from the actual brain to the formal neuron network to logical functions to the Turing machine to the computer, and aspired to create a general theory encompassing this whole range of artificial and living computers.

In the late 1940s, von Neumann began working on a general theory of "self-reproducing automata," the term he applied both to the living organisms and to complex logical-mathematical objects. Whether the brain was a computer was longer a question for him; the question was what type of computer—analog or digital—it was. Von Neumann admitted that a purely digital model for neurophysiology was too simplistic, but suggested that the answer had to combine elements of analog and digital computing: "In the lingo of computing machinery one would say that [the nerve cell] is an analog device that can do vastly more than transmit or not transmit a pulse." There was nothing unique in the non-digital aspects of the nervous system, he argued, for "vacuum tubes, electromechanical relays, etc. are not switching devices either, since they have continuous properties." If the operations of the brain and the digital computer were not entirely logical, that only brought them closer, not apart. In the end, von Neumann concluded that some "trans-continuous alternation between digital and analog mechanisms" took place both in the computers and in the nervous system, and that this was "probably characteristic of every field."[99]

While Schrödinger looked at living organisms as a physicist and identified the "physical aspect" of life with the thermodynamic order, von

Neumann looked at the nervous system "from the mathematician's point of view"[100] and identified the nervous system with a logical automaton. "The nervous system, when viewed as an automaton, must definitely have an arithmetical as well as a logical part," he argued. "This means that we are again dealing with a computing machine in the proper sense and that a discussion in terms of the concepts familiar in computing machine theory is in order."[101] Using these concepts, von Neumann compared the computer and the brain in terms of size, speed, energy dissipation, efficiency, precision, the relations between parts, and the methods of dealing with errors. Viewed as logical-mathematical automata, the brain and the computer could be described in the same terms and quantitatively compared.

Von Neumann suggested the language of self-reproducing automata as a common language for describing both the computer and the human brain. This language, composed of terms borrowed from diverse scientific and engineering disciplines, effectively blurred the boundary between

BRAIN	**AUTOMATON**	**COMPUTER**
neuron	switching/relay organ	electromechanical relay/vacuum tube
impulse	stimulus	electric pulse
excitation	on	1
quiescence	off	0
all-or-none	on/off	binary system
nervous system	formal neural network	trigger circuit
synaptic delay	reaction time	delay time
afferent neurons	input organ	input device
motor/efferent neurons	output organ	output device
associative neurons	arithmetical, control, and memory organs	arithmetical, control, and memory units

Figure 2.7
Adapted from von Neumann, "The General and Logical Theory of Automata" and "Theory and Organization of Complicated Automata."

organisms and machines. Taken out of their narrow technical context, these terms now circulated freely between the domains of neurophysiology and computing:

> The terminology used in the following is taken from several fields of science; neurology, electrical engineering, and mathematics furnish most of the words. No attempt is made to be systematic in the application of terms, but it is hoped that the meaning will be clear in every case. It must be kept in mind that few of the terms are being used in the technical sense which is given to them in their own scientific field. Thus, in speaking of a neuron, we do not mean the animal organ, but rather one of the basic components of our network which resembles an animal neuron only superficially, and which might equally well have been called an electrical relay.[102]

When von Neumann wanted to distinguish between living and non-living automata, he now had to refer specifically to "(artificial) computing machines" and "(natural) organisms."[103] One could just as easily speak about "natural automata" or "artificial organisms," since they were described in the same logical language. The powerful dual metaphor—the brain as a computer and the computer as a brain—became an essential component of the emerging universal language for men and machines.

The Making of Cyberspeak and the Emergence of Cybernetics

Wartime projects often forced specialists from diverse scientific and engineering fields to cross the conventional boundaries of their disciplines and to work together. Extensive networks of collaboration and information exchange emerged, and one of them formed around Norbert Wiener, whose assorted interests in mathematical logic, philosophy, neurophysiology, control and communication engineering, and computing brought him into close contact with specialists from all these fields. Starting in 1946, the ideas circulating in this network were discussed at a series of conferences on Circular Causal and Feedback Mechanisms in Biological and Social Systems, sponsored by the Josiah Macy Jr. Foundation. At Wiener's suggestion, conference participants decided to call "the entire field of control and communication theory, whether in the machine or in the animal, by the name *Cybernetics*,"[104] derived from a Greek word for *steersman*, and changed the series title to Conference on Cybernetics. In his recollections, Wiener described the emergence of cybernetics as a purely intellectual process based on "the essential unity of the set of problems centering about communication, control, and statistical mechanics, whether in the machine or in living tissue."[105] Viewed as a social process, however, the formation of cybernetics hardly seemed natural or smooth; it involved some determined and difficult efforts to bring together a very diverse group of researchers and to create a language that all group members could share. The intellectual construction of cybernetics as an interdisciplinary field did not happen by itself; it was closely tied to the formation of a new social network, the "cybernetics group."[106]

In the summer of 1943 Wiener, who with Rosenblueth and Bigelow had just published "Behavior, Purpose, and Teleology," received a copy of McCulloch and Pitts's article "A Logical Calculus of the Ideas Immanent in Nervous Activity." Wiener quickly discovered significant parallels between the work the Cambridge group and that of the Chicago group, and he immediately invited Pitts to MIT and introduced him to electronic computing. "He was very much interested when I showed him examples of modern vacuum tubes and explained to him that these were ideal means for realizing in the metal the equivalents of his neuronic circuits and systems," Wiener later recalled. As a result of these discussions, Wiener and his colleagues concluded that "the problem of interpreting the nature and varieties of memory in the animal has its parallel in the problem of constructing artificial memories for the machine."[107] They quickly shared these ideas with von Neumann and with the computer designers Howard Aiken and Herman Goldstine: "Everywhere," he recalled, "we met with sympathetic hearing, and the vocabulary of engineers soon became contaminated with the terms of the neurophysiologist and the psychologist."[108]

In early 1944 von Neumann and Wiener held an interdisciplinary meeting at Princeton at which several computer engineers, physiologists, and mathematicians discussed the analogy between the computer and the nervous system. Wiener evaluated the results of the meeting with great enthusiasm: "At the end of the meeting, it had become clear to all that there was a substantial common basis of ideas between the workers in the different fields, that people in each group could already use notions which had been better developed by the others, and that some attempt should be made to achieve a common vocabulary."[109]

The pronounced need for a common vocabulary highlighted a major problem of communication facing the emerging "cybernetics group." After the proliferation of wartime projects, often isolated from one another by secrecy, the terminology in each of the constituent fields of cybernetics was in flux. In control engineering, for example, standardization of terminology became a major concern: "Almost every early postwar paper made some reference to a 'new language,' to 'problems with terminology,' to the need to 'translate' the jargon of one or another group."[110]

The 1943 Rosenblueth-Wiener-Bigelow article drew heavy criticism for mixing philosophical, biological, and engineering terms.[111] Responding to critics, Wiener and Rosenblueth explained that the proposed assorted vocabulary was just a research tool that allowed them to study humans and machines with the same methods:

> We also wish to explain why we use the humanistic terms purpose and teleology in the description of the behavior of some machines. . . . We believe that men and other animals are like machines from the scientific standpoint because we believe that the only fruitful methods for the study of human and animal behavior are the methods applicable to the behavior of mechanical objects as well. Thus, our main reason for selecting the terms in question was to emphasize that, as objects of scientific inquiry, humans do not differ from machines.[112]

Wiener and Rosenblueth made it clear that, rather than offer a ready-made overarching theory for humans and machines, they were suggesting some new tools for research in this direction. Cybernetics did not emerge as the finished product of a "natural" synthesis of diverse scientific and engineering fields; on the contrary, cybernetics was proposed as an ambitious research program aimed at forging such a synthesis. "It is the purpose of Cybernetics," Wiener proclaimed, "to develop a *language* and techniques that will enable us indeed to attack the problem of control and communication in general."[113] Since some new techniques had already been developed in control and communication engineering and in neurophysiology, the creation of a common language was a crucial step that would allow a transfer of these techniques from one field to another. This common language emerged gradually over the course of ten meetings sponsored by the Macy Foundation in 1946–1953. Among the active participants of these meetings were mathematicians (Wiener, von Neumann, Pitts), engineers (Bigelow, Shannon, Heinz von Förster), philosophers (Filmer Northrop), neurophysiologists (Rosenblueth, Ralph Gerard, Rafael Lorente de Nó), psychiatrists (McCulloch, Lawrence Kubie, Henry Brosnin), psychologists (Heinrich Klüver, Kurt Lewin, Alex Bavelas, Joseph Licklider), biologists (W. Ross Ashby, Henry Quastler), linguists (Roman Jakobson, Charles Morris, Dorothy Lee), and social scientists (Gregory Bateson, Lawrence Frank, Paul Lazarsfeld, Margaret Mead).[114]

The participants discussed a whole parade of man-machine analogies: the body as a feedback-operated servomechanism, life as an entropy-reducing device, man as an "information source," human communication as transmission of encoded messages, the human brain as a network of logical elements, and the human mind as a digital computer. This assortment of mathematical models, explanatory frameworks, and appealing metaphors presented a rather chaotic and eclectic picture. What held it together was a set of interdisciplinary connections: control was viewed as an aspect of communication and vice versa; information was defined as "negative entropy" and interpreted as a measure of order, organization, and certainty, while entropy was associated with chaos, noise, and uncertainty; physiological homeostasis was identified with physical equilibrium; neurons were treated as logical elements; and thinking was made synonymous with computation.

Wiener played a central role in the attempts to bring together the diverse elements of the cybernetic medley. In particular, he managed to connect Shannon's concept of entropy as a measure of uncertainty in communication with Schrödinger's concept of negative entropy as a source of order in living organisms. Shannon's theory dealt with the precise transmission of messages. In this case, the information transmitted equaled the entropy of the information source: the greater the initial uncertainty (entropy), the greater the amount of information received in the end. For Shannon, greater entropy meant more information; for Schrödinger, however, greater entropy meant less order. Wiener reconciled these approaches by what Shannon called "a mathematical pun": Wiener considered the case of imprecise transmission, and he ingeniously redefined the notion of entropy: it now referred not to the initial uncertainty (as in Shannon's definition) but to the degree of uncertainty remaining after the message was received. Greater entropy (noise) now meant less information. Hence, while Shannon's information equaled regular entropy, Wiener's information equaled negative entropy.[115] Thanks to this simple change of sign, information (order) now opposed entropy both in communication engineering and in biophysics. Thus Wiener was able to generalize the notion of information (negative entropy) as a universal measure of organization, certainty, and order in any "system," whether technical or living: "Just as the amount of information in a system is a measure of its degree of organization, so the entropy of a system is a measure of its degree of disorganization; and the one is simply the negative of the other."[116] Introducing his seminal metaphor, "The organism is a message," Wiener wrote: "Organism is opposed to chaos, to disintegration, to death, as message is to noise."[117] Through this metaphor, the study of organisms could be translated into communication engineering, and vice versa.

Wiener further linked information with control, describing the mechanism of negative feedback in informational terms: "The information fed back to the control center tends to oppose the departure of the controlled from the controlling quantity."[118] He closely tied the notions of control and communication together and generalized them from engineering to human behavior. Wiener interpreted control as communication with feedback:

> When I control the actions of another person, I communicate a message to him, and although this message is in the imperative mood, the technique of communication does not differ from that of a message of fact. Furthermore, if my control is to be effective I must take cognizance of any messages from him which may indicate that the order is understood and has been obeyed.[119]

With equal fluency, Wiener applied the terms *message*, *memory*, and *conditioned reflex* both to the digital computer and to the nervous system. Impulses sent from one neuron to another are called *messages*: "Each neuron has its message fed into it by other neurons."[120] Memory, of the machine or of the brain, can "hold a message" and is intended for "storing information."[121] Furthermore, Wiener argued, "in the nervous computing machine it is highly probable that information is stored largely as changes in the permeability of the synapses, and it is perfectly possible to construct artificial machines where information is stored in that way," and therefore "there is nothing in the nature of the computing machine which forbids it to show conditioned reflexes."[122]

Cyberneticians combined concepts from physiology (*homeostasis* and *reflex*), psychology (*behavior* and *goal*), control engineering (*control* and *feedback*), thermodynamics (*entropy* and *order*), and communication engineering (*information*, *signal*, and *noise*) and generalized each of them to be equally applicable to living organisms, self-regulating machines (such as servomechanisms and computers), and human society. In their view, humans and machines were two kinds of *control systems*, which, *operating* in certain *environment*, pursued their *goals* (hitting a target, increasing *order*, achieving better *organization*, or reaching the state of *equilibrium*) by *communicating* with this environment, that is, sending and receiving *information* about the results of their actions through *feedback*.

Cyberspeak provided a set of concepts, which mediated between the worlds of living organisms and man-made artifacts and thus inextricably tied humans and machines together. Through cyberspeak, concepts could travel freely between mathematics, engineering, and biology. (See figure 2.8.)

Cyberspeak became a common language for neurophysiologists, control engineers, and sociologists. Feedback-controlled servomechanisms served as a universal model for physiological homeostasis, locomotion, purposeful behavior, and social equilibrium. Living organisms were viewed as thermodynamic macrosystems; the struggle between life and death was reinterpreted as a battle between negative entropy (the source of stability, organization, and order) and entropy (the force of chaos and disorganization). In cyberspeak, human communication was regarded as a problem of communication engineering (i.e., how to transmit signals accurately in the presence of noise); the intuitive human notions of certainty and uncertainty were translated into the formulas for information and entropy. Both neural cells in the human brain and vacuum tubes in electronic computers were now seen as logical elements of a cybernetic system; thus a structural anal-

MAN	**CYBERNETIC SYSTEM**	**MACHINE**
purposeful behavior	control via feedback	target seeking
human communication	information transfer	signal transmission
human brain	self-regulating device	stored-program computer
thinking	information processing	computation
brain cells	logical elements	vacuum tubes/relays
human body	feedback mechanism	servomechanism
homeostasis	equilibrium	homeostat
certainty	information	signal
uncertainty	entropy	noise
life	order	proper functioning
death	disorder	malfunctioning

Figure 2.8
Adapted from Wiener, *Cybernetics*.

ogy between the brain and the computer emerged. Both human memory and the computer storage for programs and data were construed as means for control and self-regulation and thus formed a functional analogy between the computer and the brain. Speaking of humans as control devices and describing computers in anthropomorphic terms became two sides of one coin, brought into wide circulation by cybernetics.

"The essential unity" of control and communication problems in various fields, which Wiener portrayed as a driving force behind cybernetics, may be viewed as the result, rather than a pre-existing condition, of cybernetic studies. This "unity" was deliberately constructed by the "cybernetics group," a social network of scientists and engineers aspiring to cross their disciplinary boundaries. To borrow Peter Galison's term, one might describe cybernetics as a *trading zone*, in which specialists from various fields could exchange ideas, experimental results, theories, and hypotheses.[123] Cyberspeak emerged as a common language, a pidgin of sorts, for this trading zone—a means to translate the technical terms of one field into the vocabulary of another.[124] The language of cybernetics quickly overgrew this purely technical function, however, and acquired the aura of a universal language of men, machines, and society. Cyberspeak laid a discursive basis for cyberneticians' aspirations to create a new, revolutionary interdisciplinary field.

Cyberspeak Becomes Universal

The mood of the Macy meetings was overwhelmingly enthusiastic. As Yehoshua Bar-Hillel, one of the guest participants, recalled, cybernetics and information theory "created among many of us the feeling that the new synthesis heralded in them was destined to open new vistas on everything human and to help solve many of the disturbing open problems concerning man and humanity."[125] The scope of metaphors and analogies offered by cybernetics was breathtaking. At the same meeting, the mathematician von Neumann compared digital computers to the brain composed of the McCulloch-Pitts formal neurons, while the neurophysiologist Lorente de Nó spoke of the "computing machine of the nervous system." The psychologist Klüver offered an explanation of human perception in terms of feedback; the anthropologist Bateson interpreted a transvestite ceremony as a homeostatic mechanism; the psychologist Bavelas described a game of cards as information transfer, measurable in bits. By adopting cyberspeak, researchers from various disciplines were able to describe highly specific individual phenomena in common terms understood by all participants. From this similarity of descriptions, cybernetics' enthusiasts concluded that the natural, psychological, and social processes underlying these diverse phenomena also had a common basis. For the "cybernetics group," this new description of the world in the language of cybernetics heralded a new and radically different world view.

Cyberspeak undermined some fundamental dichotomies of Western science and philosophy: mind and body, spirit and matter, the organism and the machine, the animate and the inanimate, the natural and the artificial. Classical philosophical questions were proclaimed obsolete and irrelevant. Since cybernetics replaced the old opposition of causality and teleology with the notion of feedback and explained purposeful behavior by circular causality, "the whole mechanist-vitalist controversy," in Wiener's opinion, "has been relegated to the limbo of badly posed questions."[126] The question whether machines could be considered alive was, in Wiener's view, a "semantic problem." "We are at liberty," he boasted, "to answer it one way or the other as best suits our convenience."[127] He further suggested that it was "best to avoid all question-begging epithets such as 'life,' 'soul,' 'vitalism,' and the like" and speak merely of the decrease of entropy in both humans and machines.[128]

The new cybernetic terms—*control*, *communication*, *information*, *feedback*—acquired universal meanings that could not be reduced to any particular concepts from the established scientific disciplines. "Information is information, not matter or energy," proclaimed Wiener.[129] Cyberspeak redefined all concepts it utilized: mathematical and engineering terms were extended to the human sciences, while anthropomorphic notions were generalized to cover mathematical objects and machines. This expansion of meaning was initially metaphorical, but the metaphors gradually stabilized and began to be taken literally. The neurophysiologist Ralph Gerard was among the first to notice this discursive turn; at the seventh Macy meeting, he warned other participants:

> We started our discussion in the "as if" spirit. Everyone was delighted to express any idea that came to his mind, whether it seemed silly or certain or merely a stimulating guess that would affect someone else. We explored possibilities for all sorts of "ifs." Then, rather sharply it seemed to me, we began to talk in an "is" idiom. We were saying much the same things, but now saying them as if they were so.[130]

The gradual transformation of Claude Shannon's mathematical analysis of technical communication into a general theory of human communication was a typical example of the universalization of cybernetics' claims. As early as 1928 Ralph Hartley had complained that "as commonly used, information is a very elastic term."[131] He hardly anticipated the degree of elasticity this term would gain in public discourse in the late 1940s. In 1949 Warren Weaver, the former chief of D-2 fire control section of the NDRC, who at the outset of World War II had let Shannon a contract on the study of fire control, wrote a popular account of Shannon's communication theory for *Scientific American*. The same year, Shannon's 1948 paper and an extended version of Weaver's article were published together in a book titled *The Mathematical Theory of Communication*. Weaver helped refashion Shannon's wartime work as a fundamental "information theory" with potentially unlimited applications.

Weaver proposed to interpret any form of communication as transmission of quantifiable information, including not only cases where "one mechanism . . . affects another mechanism" but also "all of the procedures by which one mind may effect another." This would involve, in Weaver's view, "not only written and oral speech, but also music, pictorial arts, the theatre, the ballet, and in fact all human behavior."[132] Weaver argued that the technical problem of accurate signal transmission, which Shannon's theory had addressed, overlapped in large part with problems emerging at the more general levels of semantics and effectiveness of communication. With a few "minor additions, and no real revision," Weaver proclaimed, Shannon's theory could be extended into semantics. Any distortion of meaning in communication, Weaver suggested, could be viewed as "semantic noise" to be eliminated by proper "adjustment."[133] For Weaver, the notion of entropy, which Shannon had associated with uncertainty, became a measure of choice, randomness, and organization, with all the rich cultural connotations of these concepts, including beauty and melody.[134] Thus, the model Shannon had suggested for technical communication in secrecy systems was extended to include all forms of interaction: between machines, between people, and between people and machines.

Shannon's mathematical model of a "general communication system" served as the conceptual framework for an original linguistic theory elaborated by the Russian-born Harvard linguist Roman Jakobson. In the active intellectual milieu of Cambridge, Massachusetts, Jakobson quickly established contacts with both Wiener and Shannon.[135] In a 1949 letter to Wiener, Jakobson called *Cybernetics* an "epoch-making" book and insisted on "the extreme parallelism between the problems of modern linguistic analysis and the fascinating problems you discuss."[136] Soon he began speaking of the "feedback process between speaking and hearing."[137]

Jakobson saw in the language of cybernetics and information theory a "modern, less ambiguous terminology,"[138] and by blending cyberspeak with traditional linguistic terminology he created his own distinct vocabulary. Instead of Ferdinand de Saussure's opposition *langue* and *parole*, Jakobson began using *code* and *message*; he substituted *subcodes* for *styles*, and replaced *contextual variations* with *redundant features*; *encoding* and *decoding* supplanted *production* and *comprehension*; and *speaker* and *listener* became *encoder* and *decoder*.

Jakobson eliminated all traces of human/machine distinction from Shannon's scheme. He combined the *information source* with the *transmitter* in one notion of *addresser*; similarly, the notion of *addressee* embraced both the *receiver* and the *destination*. Jakobson added a new concept of *contact* to denote a "psychological" dimension of communication; the *message* and the *signal* were not distinguished and were subsumed under the rubric of *message*. Instead of the *coding process*, Jakobson preferred to speak of *code*; this code, however, established the correspondence not between the message and the signal, as in Shannon's scheme, but between the message and its meaning. And finally, most important, Jakobson replaced the notion of *information* with the referential meaning of a message, or *context*, in his terms. Jakobson's overall scheme of linguistic communication, modeled after Shannon's, involved the total of six

CONTEXT

MESSAGE

ADDRESSER -- ADDRESSEE

CONTACT

CODE

Figure 2.9
Six constituent factors of verbal communication. Adapted from Jakobson, "Linguistics and Poetics."

"constituent factors":

- the *addresser* (a speaker and an encoder)
- the *addressee* (a listener and a decoder)
- the *context* (a "referent" in "another, somewhat ambiguous, nomenclature")
- the *message* sent by the addresser to the addressee
- the *code* that is "fully, or at least partially, common" to them
- the *contact,* a "physical channel and psychological connection" between them.[139]

On the basis of this scheme, Jakobson proposed a new vision of human language. He distinguished six functions of language, each related to the corresponding factor in the scheme above:

- The emotive (expressive) function aims at a "direct expression of the speaker's attitude toward what he is speaking about."
- The conative (imperative) function brings focus on the addressee and finds its "purest grammatical expression in the vocative and imperative."
- The referential (cognitive, denotative) function has an "orientation toward the context."
- The poetic (aesthetic) function is the dominant function of verbal art, for it sets "focus on the message for its own sake."
- The metalingual (metalinguistic) function is used "whenever the addresser or the addressee needs to check up whether they use the same code"—for example, when the meaning of words is discussed.
- The phatic function serves "to establish, to prolong, or to discontinue communication, to check whether the channel works," and so on.[140]

Jakobson argued that this new conceptual scheme explicated some aspects of language that were not recognized by traditional linguistics. In his view,

REFERENTIAL

POETIC

EMOTIVE -- CONATIVE

PHATIC

METALINGUAL

Figure 2.10
Six basic functions of verbal communication. Adapted from Jakobson, "Linguistics and Poetics."

unlike "the less 'biased' communication engineers," many linguists overlooked the phenomenon of "code variability," which was pertinent to the use of metaphors: "Metaphoric creations are not deviations but regular processes of certain stylistic varieties, which are subcodes of an overall code."[141] Jakobson did not simply translate an existing linguistic theory into cyberspeak; he used cybernetic concepts to build a new theoretical framework for linguistics.

Wiener, in turn, referred to Jakobson's work to argue that cybernetics fitted well with modern linguistics. He cited Jakobson and the mathematician Benoit Mandelbrot in describing human communication as a "game played in partnership by the speaker and the listener against the forces of confusion."[142] In other words, while Jakobson borrowed cybernetic concepts to build a linguistic theory, cyberneticians were "discovering" cybernetic phenomena in his linguistics. Making a formidable example of a closed loop, cybernetic concepts traveled in a circle, extending from cybernetics into linguistics and then coming back as if they were original linguistic notions.

The historian Geoffrey Bowker has described this circular process as a chief feature of the language of cybernetics. It served an important social function by supporting "legitimacy exchange" among scientists: "An isolated scientific worker making an outlandish claim could gain rhetorical legitimacy by pointing to support from another field—which in turn referenced the first worker's field to support its claims. The language of cybernetics provided a site where this exchange could occur." In Bowker's words, the author of the "conditional probability machine," A. M. Uttley, "used mathematics to support his physiology and physiology to support his mathematics, using cybernetic terminology to spiral between the formal properties of classification machines and the nature of the brain."[143]

Cybernetics did not merely describe computers metaphorically as brains; the brain itself was conceptualized in logical and engineering terms, and these concepts then returned to computing, serving as a basis for the impressive "discoveries" of man-machine analogies. On the first pages of his *Cybernetics*, Wiener suggested the computer as a model for the nervous system: "It became clear to us [Wiener and Pitts] that the ultra-rapid computing machine, depending as it does on consecutive switching devices, must represent almost an ideal model of the problems arising in the nervous system."[144] A few pages down, he turned this analogy around and described the computer itself in neurophysiological terms: "The modern ultra-rapid computing machine was in principle an ideal central nervous system to an apparatus for automatic control."[145] In another example, physiological homeostasis was conceptualized as a feedback-controlled servomechanism, while servomechanisms themselves were described in anthropomorphic terms. The historian Lily Kay argued that "signifying homeostasis as negative feedback and then resignifying such servomechanisms as organismic homeostasis amounted to a circularity."[146] The dialogue between molecular biologists and control engineers in the language of cybernetics, in the words of the historian Evelyn Fox Keller, resulted in a "bootstrap process of modeling organisms and machines, each upon the other." [147] If we allow ourselves to resort to a cybernetic metaphor, we might describe this process as a feedback loop of man-machine metaphors: the more anthropomorphic the machines looked, the more machine-like the human beings appeared.

Whether individual cyberneticians intended this or not, the logic of cybernetic discourse propelled the universalization of their claims. McCulloch and Pitts argued only that even simple formal neural networks could fulfill complex logical functions. In von Neumann's interpretation, however, McCulloch and Pitts had in effect found a means to imitate "any conceivable form of behavior," since such networks could realize any logical function:

> McCulloch and Pitts's important result is that any functioning in this sense which can be defined at all logically, strictly, and unambiguously in a finite number of words can also be realized by such a formal neural network. . . . Since the converse statement is obvious, we can therefore say that there is no difference between the possibility of describing a real or imagined mode of behavior completely and unambiguously in words, and the possibility of realizing it by a finite formal network. . . . There is no doubt that any special phase of any conceivable form of behavior can be described "completely and unambiguously" in words. This description may be lengthy, but it is always possible.[148]

While McCulloch and Pitts drew from their analysis a pessimistic conclusion about the limitations of our knowledge of the world, von Neumann interpreted the same article as a source of optimistic predictions of the universal capabilities of formal neuron networks. As the neuroscientist Günther Palm has observed, McCulloch and Pitts were so "breathtakingly arrogant in their use of mathematical formalism" in their 1943 paper that this made "the mathematical portions of the paper, i.e. almost all of it, quite unreadable even for mathematicians."[149] As McCulloch himself admitted, this paper might have remained completely unknown to biologists had it not been for von Neumann's efforts[150]; as a result, it was von Neumann's broad reading of this paper that became its standard interpretation. Similarly, while Turing initially called a particular logical machine "universal" because it could imitate the operations of any other abstract computing machine, this notion of universality was extended to any type of thinking and behavior. In von Neumann's interpretation, Turing, McCulloch, and Pitts had demonstrated that "what their automata can do can be described in logical terms and, conversely, that anything which can be described rigorously in logical terms can also be done by automata."[151] Later von Neumann tacitly replaced the narrowly defined "logical terms" with a very broadly conceived notion of "a finite number of words," which could apply to any fragment of human speech. A modest statement of the possibility to implement logical functions in a logical machine thus magically turned into the sweeping claim of the universal capabilities of automata.

First the cyberneticians asked grandiose questions: What is life? How do we know the world? What governs human behavior? Next they translated these questions into cyberspeak, then substituted for them much narrower versions that could be answered within a particular specialized field of study: mathematics, logic, control theory, or communication engineering. Then they said that these grandiose questions had now been "precisely defined." After obtaining the answer to a "precisely defined" question, they claimed that it could be applied universally, far beyond the original specialized field. Thus cyberspeak became a universal language for answering grandiose questions.

The Cybernetics Bandwagon

Upon its publication in 1948, Wiener's *Cybernetics* gained enormous popularity, which its author hardly expected. The *Saturday Review of Literature* noted that it appeared "impossible for anyone seriously interested in our civilization to ignore this book." "It is," the magazine commented, "a 'must' book for those in every branch of science." A large portion of the book was occupied by complex mathematical chapters, which a broad audience could not possibly understand. These chapters, although "largely irrelevant,"[152] fulfilled an important rhetorical function: they greatly impressed lay readers, thus conferring legitimacy on the bold claims made in a plain language in the rest of the book. Cybernetics promised solutions to a wide range of social, biological, and technological problems through computer modeling, information processing, and feedback control. Complex social and biological phenomena looked simpler and more manageable when described in cybernetic terms. Masking the differences in the nature and the scale of those phenomena, the common language of cybernetics allowed one to use the same mathematical techniques across a wide range of disciplines. When translated into cyberspeak, biological, technological, and social problems all seemed to have similar—cybernetic—solutions. Taking cybernetic claims seriously, many biologists and social scientists pushed the boundaries of cybernetics even farther than Wiener and his colleagues originally envisioned.

The popular press hailed digital computers as "electronic brains."[153] *Scientific American* published an accessible account of cybernetics under the provocative title "Man Viewed as a Machine."[154] The computer specialist Frank H. George threw a challenge to the readers of the English journal *Philosophy*: "You can't tell me anything that your wife can do that a machine can't (in principle)."[155] Political scientists spoke of the "nerves of government."[156] Engineers, economists, and journalists described the bright technological future populated with intelligent robots.[157] Business consultants began to sell "management cybernetics."[158] Molecular biologists conceptualized the gene as "the smallest message unit" that could "make a yes-no decision" and measured "the information content and error rate of living things."[159] Biological specificity was "re-represented through the scriptural tropes of information—*message*, *alphabet*, *instructions*, *code*, *text*, *reading*, *program*. The narratives of heredity and life [were] rewritten as programmed communication systems."[160]

While borrowing cybernetic concepts, biologists and social scientists tended to leave out the complex mathematical techniques of control engineering and communication theory. The author of a 1961 overview observed that biologists "have been aware of information theory and have made qualitative use of some of its concepts" but concluded that "no explicit, and especially no quantitative use of information theory has, however, been made in practice."[161] As Lily Kay put it, information theory functioned in biology "as a discursive rather than mathematical tool."[162] In other words, the popularity of cybernetics consisted largely in the spread of cyberspeak. Geoffrey Bowker has argued that cyberspeak turned into "a universal language for a new age" largely because jumping on the cybernetics bandwagon made it easier to attract funding for research:

> The advantage for scientists from whatever discipline of being given a remit by cybernetics to use interesting and glamorous words was clear. Anyone tapping into the network of words used by cybernetics would be tapping into the network of problems that cyberneticians were aiming to solve. These, by definition (since cybernetics was the science of the current conjuncture) were at the cutting edge of military and industrial research. Grant applications could follow.[163]

Some pioneers of cybernetics felt uneasy about such unrestrained uses of cyberspeak and about their unruly cultural ramifications. Shannon initially hesitated to apply the thermodynamic term *entropy* to communication engineering and emphasized that his notion of information had nothing to do with the "semantic aspects of communication."[164] As Shannon's mathematical theory of communication (packaged as "information theory") began to spread widely into biology, psychology, and economics, the cultural connotations of his technical terms quickly span out of control. In a 1956 essay titled "The Bandwagon," Shannon sounded a cautionary note:

> [Information theory] has perhaps been ballooned to an importance beyond its actual accomplishments. Our fellow scientists in many different fields, attracted by the fanfare and by the new avenues opened to scientific analysis, are using these ideas in their own problems. . . . It will be all too easy for our somewhat artificial prosperity to collapse overnight when it is realized that the use of a few exciting words like *information, entropy, redundancy,* do not solve all our problems.[165]

Eventually, Shannon withdrew from the public eye and refused to speak about his "information theory."[166]

Wiener also objected to what he saw as a misuse of the words *automatization* and *cybernetics* by "a group of eager beavers." "I cannot protest against the free use by any man of a word [*cybernetics*] that I intended as a common noun," he wrote in 1954, "but I do protest against the appropriation of words covering a certain philosophy of engineering by many engineers with only a fragmentary idea of what these words mean."[167] On the one hand, Wiener actively promoted cyberspeak as a universal language; on the other, he tried—apparently in vain—to limit its uses. The tendency toward universality in the cybernetic discourse quickly overpowered his attempts to control the meaning of *cybernetics*.

Though he was hailed as a "prophet" of the new age of automatic machinery, Wiener held ambivalent views about the social implications of cybernetics. He regarded automatic machines as both "threat and promise."[168] He proclaimed the advent of a "second industrial revolution" that would bring about "the automatic factory and the assembly line without human agents."[169] This revolution, in his view, carried "great possibilities for good and for evil."[170] Cybernetic techniques and technologies, he argued, "open to us vistas of a period of greater plenty that the human race has ever known, although they create at the same time the possibility of a more devastating level of social ruin and perversion than any we have yet known."[171] Wiener warned that automation was "bound to devalue the human brain."[172] "The skilled scientist and the skilled administrator may survive," he wrote, "[but] the average human being of mediocre attainments or less has nothing to sell that it is worth anyone's money to buy."[173] Wiener was deeply critical of capitalist America. He did not believe in the ability of the "invisible hand" of the free market to establish economic and social equilibrium (*homeostasis*, in cybernetic terms). His social outlook was overtly pessimistic: "There is no homeostasis whatever. We are involved in the business cycles of boom and failure, in the successions of dictatorship and revolution, in the wars which everyone loses."[174]

Cybernetics, in Wiener's view, provided hope for social change. Two years after *Cybernetics* he published *The Human Use of Human Beings: Cybernetics and Society*, in which he developed a cybernetic critique of the pervasive controls over social communication under McCarthyism in the United States and under Stalinism in Russia. He believed that describing society in cybernetic terms as a self-regulating device would make people realize the danger of "the control of the means of communication" as "the most effective and most important" anti-homeostatic factor, which could drive society out of equilibrium.[175] While Wiener used cyberspeak to emphasize the need for unencumbered communication, his friends among social scientists often interpreted cybernetics as an efficient tool for rational social control. Wiener did not share their "excessive optimism" and argued that "in the social sciences we have to deal with short statistical runs, [and we cannot] be sure that a considerable part of what we observe is not an artifact of our own creation."[176] Again, his attempts to control the uses of cyberspeak proved futile.

While Wiener hoped to make cybernetics a scientific basis for liberal politics, the language of cybernetics became a convenient rhetorical tool for very diverse political discourses. In December of 1948 *Le Monde* published a review of *Cybernetics* by the Dominican friar Père Dubarle, who contemplated the possibility of an all-powerful "*machine à governer*" that would make the state "the only supreme co-coordinator of all partial decisions." "In comparison with this," wrote Dubarle, "Hobbes's *Leviathan* was nothing but a pleasant joke. We are running the risk nowadays of a great World State, where deliberate and conscious primitive injustice may be the only possible condition for the statistical happiness of the masses: a world worse than hell for every clear mind."[177] While Dubarle viewed cybernetics as the embodiment of a totalitarian spirit, Wiener attempted to make the cybernetic *machine à governer* an element of the cybernetic critique of totalitarianism. He employed cyberspeak to criticize both capitalism and communism: "A sort of *machine à governer* is thus now essentially in operation on both sides of the world conflict, although it does not consist in either case of a single machine which makes policy, but rather of a mechanistic technique which is adapted to the exigencies of a machine-like group of men devoted to the formulation of policy. Père Dubarle has called the attention of the scientist to the growing military and political mechanization of the world as a great superhuman apparatus working on cybernetic principles."[178] As it turned out, both Wiener's desired social equilibrium and the despised "mechanization of the world" were based on the same cybernetic principles. Cybernetics thus could not be tied to a single political agenda; instead, different parties were able to use cyberspeak to express widely divergent social views.

The fate of Wiener's cybernetics was deeply ironic. Wiener developed a cybernetic critique of the manipulation of social communications for political purposes; however, the same language of cybernetics was employed to develop pragmatic sociological theories within a conservative political framework.[179] After Hiroshima, he became an outspoken critic of the military-industrial complex; yet cybernetic techniques and technologies were widely used by the military.[180] He insisted that information could not be a commodity; nevertheless, the cybernetic techniques of measuring and processing information facilitated the marketing of this product.[181] While he spoke against military secrecy, information theory greatly improved cryptography. In Wiener's view, cybernetic knowledge would liberate rather than further enslave the individual. Cybernetic analysis of control mechanisms, however, helped create new controls. Wiener hoped that his cybernetic analysis would expose the flaws of both capitalism and communism. Yet capitalism fully embraced cybernetics and quickly appropriated it to its needs.

In the next chapter, I will examine the reaction to cybernetic ideas on the communist side of the Iron Curtain.

This Page Intentionally Left Blank

3

"Normal Pseudo-Science"

They berated cybernetics quite vigorously but with certain . . . indifference and even fatigue. This looked like a farce, which was to come after the tragedy [of genetics]. . . . Cybernetics emerged as a normal pseudo-science.

—Il'ia Novik[1]

In 1953—the last year of the Stalinist era of Soviet history—volume 20 of *The Great Soviet Encyclopedia*, an authoritative compendium of all human knowledge befitting the Soviet citizen, came out. Similarly to the French *Encyclopédie* of the eighteenth century, *The Great Soviet Encyclopedia* served not merely a descriptive but also a normative function in the Soviet "Enlightenment": it defined the boundaries of knowledge, certified the validity of scientific theories included in its volumes, and also—indirectly—denied the validity of those theories that did not acquire the privilege of being featured in the *Encyclopedia*. It was in volume 20 that the word *cybernetics* should have appeared, in accordance with the Russian alphabet. But it was not there. The alphabetical order was superseded by the political order of things, and ex officio cybernetics remained a nonexistent entity.

The mathematical section of the *Encyclopedia* was edited by Andrei Kolmogorov, a leading Soviet mathematician, a full member of the Soviet Academy of Sciences, director of the Institute of Mathematics at Moscow University, and a department head at the Mathematical Institute of the academy. As was discussed in the previous chapter, Kolmogorov's intellectual trajectory had closely paralleled the research interests of Norbert Wiener, the "father of cybernetics." Both men had worked on prediction theory of stationary stochastic processes, which proved useful in control and communication engineering and laid a mathematical foundation of cybernetics. Both had had broad interests in philosophy, in logic, and in the application of mathematical methods to biology. Yet in the early 1940s their research paths had diverged radically. Wiener, after a brief encounter with military-oriented control engineering, had turned to the exploration of general mechanisms of control and communication in organisms and machines—a field of study he named *cybernetics*. Kolmogorov, on the other hand, had barely escaped serious political trouble after his confrontation with Trofim Lysenko over the validity of mathematical methods in biology, and subsequently avoided any association with the life sciences and focused instead on solving mathematical problems of ballistics.

In the divergent intellectual trajectories of the two outstanding mathematicians one may see a reflection of the different fates that awaited cybernetics on the two sides of the Iron Curtain. In the United States, in the historical context of the Cold War, digital computing and cybernetics grew out of wartime engineering projects and embodied some essential patterns of military control and communication. The rapid development of computer technology occurred in close connection with the spread of cybernetic man-machine metaphors and fostered a popular vision of human thinking and behavior as forms of rational computing. In the Soviet Union, the military and ideological pressures of the Cold War shaped the relationship between computing and cybernetics in a different way.

In this chapter I examine the Soviet reception of American cybernetics and its impact on the early history of Soviet digital computing. Soviet computing was shaped by the tension between the practical goal of developing modern sophisticated weapons and the ideological urge to combat alien influences. The first trend ("overtake and surpass") dominated in Soviet physics, and the second ("criticize and destroy") reigned in biology; computing was an interesting borderline case. The importance of digital computers for defense research pointed in the "overtake and surpass" direction, whereas the ideological campaigns of late Stalinism against "reactionary and idealistic" Western science fostered the "criticize and destroy" tendencies. Western computer advances became the subject of intense scrutiny, eager imitation, and ideological criticism, all at the same time.

Soviet computer specialists had to walk a fine line between two mortal dangers: falling behind the West in computing and following Western trends too closely. To protect themselves from potential ideological complications, they resorted to the discursive strategy of "de-ideologization," distancing computing from cybernetics. They emphasized the narrow technical functions of computing and information theory, ignoring any potential conceptual innovations. This strategy severely limited the field of computer applications and eliminated the prospects of biological and sociological modeling. In the Soviet Union, the digital computer was viewed as a giant calculator and was stripped of all cybernetic metaphors. Paradoxically, it was seen both as an indispensable tool for designing and controlling weapons and as a cultural symbol of technology freed from ideology. The ideological controversy over cybernetic man-machine analogies and the attempts to "de-ideologize" Soviet computers reflected a fierce discursive clash between newspeak and cyberspeak.

Cybernetic Ideas in a Soviet Context: Pro and Contra

Cybernetic ideas looked both appealing to Soviet culture and threatening to the established interdisciplinary boundaries and political divisions. Soviet scientists and engineers worked productively in several areas that fell under the rubric of cybernetics. They independently developed a number of mathematical and engineering techniques that formed the technical basis of cybernetics, and conducted extensive biophysical and physiological studies in the cybernetic spirit. Many of the essential intellectual ingredients of cybernetics were present in the Soviet context, but Soviet scholars at that time could hardly contemplate the idea of a grand synthesis that inspired the American "cybernetics group." The interdisciplinary boundaries erected by the Stalinist champions of the officially approved "scientific schools" discouraged free circulation of ideas among fields of study. Besides, several major contributors to American cybernetics independently became subjects of ideological controversy in the Soviet Union, and such arguments may have cast a shadow of suspicion on their cybernetic work as well. Diverse cybernetic ideas evoked both positive and negative attitudes in the Soviet context, and it was not initially clear in which direction the balance would tip.

Many threads of the cybernetic quilt could be stretched back to Russian origins. In his *Cybernetics*, Wiener cited Ivan Pavlov's work on conditional reflexes, Andrei Kolmogorov's study of stationary time series, and Nikolai Krylov and Nikolai Bogoliubov's work on ergodic theory.[2] As was noted in chapter 2, a 1935 article co-authored by the Russian geneticist Nikolai

Timoféeff-Ressovsky inspired Erwin Schrödinger to conceptualize problems of genetics in terms of quantum theory. Warren McCulloch and Walter Pitts's formal logical model of a neuron was developed in close contact with the mathematical biophysics group (led by the Russian-born physicist Nicolas Rashevsky) at the University of Chicago.

The *Markov chain*—a central notion of cybernetics that applied to a wide range of phenomena, from natural language to the stock market—had originated in Russia. Claude Shannon's application of information theory to natural language drew heavily on and partly reinvented the work of the prominent Russian mathematician Andrei Markov Sr., who had offered an original stochastic model of natural language at the turn of the twentieth century. In Shannon's theory of communication, linguistics, mathematics, and engineering formed a remarkable cybernetics-style feedback loop.

Shortly before the Russian proletariat cast away the chains of capitalism and put on the chains of communism, another set of chains had entered the historical arena. In the early 1900s, Markov had developed a statistical theory of "chained events," which he defined as sequences of mutually dependent random variables. In 1913, in a pioneering study of natural language with stochastic methods, he had used this theory to analyze the alternation of vowels and consonants in Aleksandr Pushkin's famous poem *Eugene Onegin*.[3] Markov assumed that the probability of a particular letter's being a vowel depended solely on the letter that immediately preceded it. In more abstract mathematical terms, he studied the properties of sequences ("chains") of random events in which the probability of any future event was determined by the current state and did not depend on all the previous events in the chain. Generalized for the case of continuous time, Markov's theory later developed into the theory of stochastic processes (*Markov processes*), or *random walks*. The linguistic origins of Markov's study were quickly forgotten, and Markov processes turned into an abstract mathematical concept.

The "random walk" of Markov's ideas led from linguistics to mathematics to communications engineering to information theory and ultimately back to linguistics. In his "Mathematical Theory of Communication," Claude Shannon based the notion of "information source," whether animate or inanimate, on a stochastic system with a finite number of states and transition probabilities that depended only on the current state. "To make this Markoff process into an information source we need only assume that a letter is produced for each transition from one state to another," wrote Shannon, reinventing Markov's original idea.[4] Shannon argued that a series of Markov processes would produce simple artificial languages that approached natural language, and he illustrated this idea with a series of approximations to English. Curiously, Shannon's efforts to extend the theory of technical communication into linguistics brought information theory back to one of its own roots.

Not only the abstract concepts of cybernetics but also its practical applications fell on a fertile soil in the Soviet Union. The idea of automation looked particularly attractive to the Soviet leaders. During the Stalinist industrialization drive, automation became something of a Party slogan. In the 1930s, the Soviets were more than eager to follow American examples: a giant steel plant in Magnitogorsk closely imitated the U.S. Steel plant in Gary, Indiana, and an equally formidable automobile plant in Gor'kii was modeled after Ford's River Rouge plant. The leadership of the Gor'kii plant also borrowed some management principles from the Ford Motor Company.[5] In the 1930s, the term *dispetcherizatsiia*—a calque of the English word *dispatching*—entered Party slogans in the widely promoted "campaign for dispatching." In March of 1934, at a conference on dispatching in Moscow, the Committee on Automation, Remote Control, and Dispatching was set up. On the basis of this committee, the Soviet Academy of Sciences soon established the Commission on Automation and Remote Control, which began publishing a journal titled *Avtomatika i telemekhanika* [*Automation and Remote Control*].[6] In May of 1935 more than 600 scientists and engineers took part in the First All-Union Conference on Remote Control and Automation in Moscow. Among other things, conference participants discussed such topics as "automatic calculating-computing mechanisms" and the "problem of thinking and automation."[7] The conference adopted a resolution proclaiming that automation and remote control made it possible to control production "without human interference" and to organize "precise centralized control of production on all stages without exception."[8] In 1938–39 the Academy transformed this commission into a Committee on Automation and Remote Control; later, an Institute of Automation and Remote Control was created. That institute pursued both fundamental and applied research on the design of production control devices, and also developed techniques for automated management.

The Soviet Union had a vigorous native tradition in control engineering.[9] In the 1940s and the early 1950s, two strong groups of researchers under the direction of Academician Aleksandr Andronov, one at the Institute of Automation and Remote Control in Moscow and one at Gor'kii University, worked productively on the theory of automatic control.[10] Andronov's research directly addressed some of the problems Wiener grouped under the cybernetics umbrella, including nonlinear control systems and self-organization.[11] In August of 1949 Andronov wrote from Gor'kii to his close associate in Moscow: "I am very interested in Wiener's *Cybernetics*, but have not acquired it yet. *If you know where to find it, please let me know*."[12] Andronov soon obtained a copy of Wiener's book, enthusiastically discussed it in his circle, and eagerly lent it to his colleagues.[13]

Shannon's idea to use Boolean algebra to describe the functioning of relay switching circuits, which played an important role in the development of digital computing and fostered the cybernetic analogy between the computer and the mind, also had parallels in the works of Soviet scientists and engineers. In January of 1935 V. I. Shestakov, a physicist at Moscow University, completed his manuscript "The Algebra of Relay Circuits," which became the basis of a dissertation he defended at Moscow University in 1938. Shestakov's idea of logical algebraic description of relay circuits preceded Claude Shannon's 1937 master's thesis on this topic by a couple of years. Shestakov's work, however, was not published until 1941.[14]

The "all-or-none" principle of nervous activity was theoretically derived and experimentally studied by biophysicist Petr Lazarev, who directed the Institute of Physics and Biophysics (organized in Moscow in 1919).[15] Soviet biophysicists worked in close contact with engineers and used various technical devices both as experimental tools and as models of specific physiological mechanisms. Lazarev became a member of the Commission on Automation and Remote Control; his works emphasized the significance of such devices as automatic registers and amplifiers for the development of physiology.[16]

The feedback mechanism was adopted as a model for human physiology by the physiologist Nikolai Bernshtein, whose works were discussed in chapter 1. In the 1920s and the 1930s, he organized biophysical laboratories at the Central Institute of Labor and the Institute of Physical Culture in Moscow. In a series of experimental studies of human motor activity, Bernshtein interpreted locomotion not as a sequence of Pavlovian reflexes but as a feedback-type cycle of actions and corrections. In 1934 Bernshtein proposed replacing the notion of a "reflex arc" with that of a "reflex circle,"[17] which he compared to a servomechanism.[18]

Pavlovian physiology had an ambivalent relationship with cybernetics. Wiener called Pavlov a "great scholar"[19] and viewed reflex theory as an important source for cybernetics. In the Soviet Union, ironically, cyclical models in neurophysiology were developed in direct opposition to reflex theory. Bernshtein, in particular, argued that the Pavlovian doctrine, based on the concept of "reflex arc," presupposed a rigid unidirectional link between the stimulus and the reaction and did not leave any room for a cyclical relation between the two. In the late 1940s and the early 1950s, when the Pavlovian theory occupied the dominant position in Soviet physiology, Bernshtein's break with orthodoxy resulted in his marginalization in the physiological community and in the public condemnation of his mathematical approach. The dogmatic rulers of Soviet physiology censured his proto-cybernetic theory as non-Pavlovian if not directly anti-Pavlovian.

As was typical of the Soviet ideological discourse, any deviations from the orthodox Pavlovian doctrine were harshly condemned, but the exact meaning of this doctrine was a matter of serious debate. In a fierce competition over the leading positions in Soviet physiology, Pavlov's former students advanced rival interpretations of their mentor's teaching, attempting to lay exclusive claims to his legacy. In one instance, Pavlovian reflexes were interpreted so broadly that they included feedback loops. In the early 1930s, Petr Anokhin, a former researcher in Pavlov's laboratory, proposed to group all physiological processes into a set of *functional systems* responsible for specific functions, such as breathing, swallowing, or locomotion.[20] In a series of experiments, Anokhin cut a dog's nervous channels, intercrossed them, and observed how various centers of nervous activity adapted to the change and restored their functions. In his view, each functional system worked in a closed loop: signals from peripheral organs "sanctioned" those patterns of excitation in the center that caused favorable effects ("sanctioning afferentation") and thus facilitated the restoration of damaged functions. While other Pavlovians emphasized the role of the central nervous system and viewed the cerebral cortex as the sole governing organ, Anokhin shifted the emphasis to the interaction between the center and the periphery as a key to understanding physiological processes.

Wiener's reverence toward Pavlov might have made a good impression in the context of the Soviet postwar ideological campaign for "patriotism" (read: the Russian national priority in various fields of science), but his other references and associations could easily get cybernetics into trouble. Margaret Mead, an active participant of the Macy conferences on cybernetics, was labeled in the Soviet press a "psychoracist" for her analysis of national character, which ignored the notion of class struggle.[21] Nicolas Rashevsky's works on mathematical biophysics and mathematical sociology were branded "pseudoscientific nonsense" that "did not have a grain of real science" and served only "to block the road toward the study of objective laws of nature and society with a smoke screen of equations."[22] Roman Jakobson was called in the Soviet press a "typical bourgeois cosmopolitan scholar"[23] and a "sworn enemy of Marxist philosophy and socialism [who is] deliberately preaching idealistic nonsense."[24] His attempts to use mathematical methods to estimate the average number of distinctive features of the Russian phoneme (5.79) were thoroughly ridiculed as a variety of "formalism":

> What can, say, a phoneticist obtain from the figure 5.79 for a real description of some phoneme of the Russian language? Nothing! . . . The structural approach is not a method of linguistic research but merely a technique of formal mathematical representation of the results of research, and this form of representation does not add any new knowledge of language.[25]

A similar charge of "formalism" was leveled against the engineer Mikhail Gavrilov of the Institute of Automation and Remote Control, who, following the work of Shannon and Shestakov, used mathematical methods for synthesis and analysis of relay and switching circuits. Gavrilov proved that any predicate calculus formula could be represented by a relay switching circuit, and vice versa. His 1950 book *The Theory of Relay Switching Circuits* was severely criticized for "formalism" and "idealism."[26] Some critics described his engineering applications of logic as an attempt to "dehumanize logic"; his doctoral dissertation defense, it was said, "resembled a battle."[27]

From an ideological perspective, potentially one of the most damaging associations of cybernetics was Wiener's reference to the work of the famous physicist Erwin Schrödinger. Back in the 1930s, militant Soviet philosophers who opposed quantum mechanics had made Schrödinger, a leading Western researcher in this field, a target of ideological attacks; they had accused him of "a deviation toward subjective idealism."[28] His inroad into biology in the 1944 book *What Is Life?* further complicated the situation. That book came out in the Russian translation in 1947, right in the middle of a fierce battle between Soviet geneticists and their opponents led by Trofim Lysenko. Schrödinger's defense of the chromosome theory brought the authority of modern physics explicitly to the geneticists' side, and this immediately made him a mortal enemy of the Lysenkoites. In the spring of 1948, at a meeting at the Institute of Physics, Aleksandr Oparin, the head of the Biology Division of the Academy of Sciences, called *What Is Life?* "adverse to our ideology" and "harmful."[29] Attacking Schrödinger became an essential part of the Lysenkoites' campaign against genetics.

Focusing on the most ideologically vulnerable part of Schrödinger's argument, the Lysenkoites made his brief excursion into theology in the epilogue to *What Is Life?*—largely irrelevant to the rest of the book—the main target of their criticism. In this epilogue, Schrödinger offered an unusual theological explanation of the apparent contradiction between the view of the human body as a mechanism and the idea of free will. In his view, atoms obeyed both free will and the God-given laws of nature, because, as he had learned from the early Upanishads, in some deep sense the personal self, which possessed free will, equaled God, "the omnipresent, all-comprehending eternal self."[30] Schrödinger's unorthodox religious views caused some controversy in Ireland, where his original publisher refused to release the book and dispersed the type, but this was nothing compared to the storm of ideological criticism raised against Schrödinger in the Soviet Union.

The Lysenkoites cleverly used Schrödinger's ruminations over religious questions to discredit his entire line of physical reasoning in biology. When drafting his speech against "reactionary" and "idealistic" genetics for the July-August 1948 session of the Lenin All-Union Academy of Agricultural Sciences, Lysenko did not even attempt to address Schrödinger's physical arguments. "Since I am no physicist," said Lysenko with pretended humility, "I shall say nothing concerning the methods of physics which Schrödinger combines with biology."[31] Instead, he directed his criticism chiefly at Schrödinger's religious views. Lysenko cunningly shifted the blame for Schrödinger's ideological "errors" on all Soviet geneticists ("our Morganists"):

> The true ideological content of Morgan's genetics has been revealed (to the discomforture of our Morganists) by the bourgeois physicist Erwin Schrödinger. In

> his book, *What Is Life? The Physical Aspect of the Living Cell,* he draws some philosophical conclusions from the chromosome theory, of which he speaks approvingly. Here is his main conclusion: ". . . the personal self equals the omnipresent, all-comprehending eternal self." Schrödinger regards this conclusion as "the closest a biologist (i.e., a Morganist—T.L.) can get to proving God and immortality at one stroke."[32]

Soviet ideologues could easily comprehend this simplified critique of genetics, unburdened by either physical or biological terminology. In particular, the anti-religious argument proved much to the liking of Joseph Stalin, a former seminary student. While editing Lysenko's draft, Stalin crossed out the entire second section, devoted to criticism of "bourgeois biology," preserving only one paragraph: Lysenko's critique of Schrödinger. Stalin also did Schrödinger a small favor by deleting the pejorative epithet *bourgeois*—probably for the sake of rhetorical consistency, since class-based analysis of science sounded obsolete in the context of the Cold War.[33]

After Lysenko's much-publicized speech, Schrödinger became a prominent target of vitriolic ideological attacks. In December of 1948 an official letter signed by the president of the Soviet Academy of Sciences and by the Minister of Higher Education charged that *What Is Life?* was "openly preaching idealism."[34] In 1953 the journal *Voprosy filosofii* accused Schrödinger of "subjective idealism" and labeled him a "reactionary bourgeois scientist" and a "learned lackey of the bourgeoisie."[35] The journal *Priroda* further charged him with an attempt to extend the idealistic philosophy of indeterminism into biology and thus to carry over his philosophical errors from physics into genetics.[36] One "patriotic" physicist from Moscow University accused Schrödinger of bowing to the "sworn enemies of our Soviet biologists" and "malevolent emigrants."[37]

Instead of earning him a credit for citing a Russian source, Schrödinger's extensive references to the work of the Russian-born biologist Nikolai Timoféeff-Ressovsky further aggravated the situation. In 1945 Timoféeff-Ressovsky, a Soviet citizen who had remained in Germany and continued his research during World War II, was arrested by the Soviet troops and sent to a labor camp.[38] The political troubles of Timoféeff-Ressovsky cast a long dark shadow of ideological suspicion over his scientific work and, by association, over the work of Schrödinger.

The diverse and eclectic set of ideas, models, and metaphors that composed cybernetics evoked the whole range of attitudes in the Soviet context—from highly positive to utterly negative. The fate of cybernetics as a whole seemed quite uncertain; in the atmosphere of total uncertainty of late Stalinism, a small event could tip the balance and send American cybernetics either to the top of Soviet priorities in science or to the dustbin of history. Such an event—indeed a chain of such events—occurred in the early 1950s and shaped the Soviet reception of cybernetics in a most unpredictable way.

"Russian Scandal" at the Root of Cybernetics

In 1913 Norbert Wiener, a fresh 18-year-old Ph.D. from Harvard, arrived in England to study logic, philosophy, and mathematics with the luminaries of Cambridge University. He soon met Frederic Bartlett, a young psychologist who was involved in a series of experiments on visual perception in the newly opened Laboratory of Experimental Psychology at Cambridge. "I was fascinated," Bartlett later recalled, "by the variety of interpretations which different people then achieved, all of which they said they 'saw,' of the same diagrams and pictures" shown to them by the experimentalist.[39] Dissatisfied with the accepted "exact" experimental technique, which involved recollection of lists of nonsense syllables, Bartlett was looking for a new method of studying human memory. Convinced that memory was a social and cultural phenomenon, he wanted to allow cultural associations and patterns to play a role in the experiment, while still retaining a strict experimental procedure. According to Bartlett, Wiener helped turn his research in a new direction:

> We became close friends and had tremendous arguments with one another. One day, when I had been talking about my experiments, . . . he said: "Couldn't you do something with 'Russian Scandal' as we used to call it?" That was what led to the method I later called "The Method of Serial Reproduction," one which, in varied form, was to contribute much to the final working out of my experiments.[40]

Russian Scandal was another name for Telephone, a parlor game in which players sitting in a circle pass a message from one to another by whispering and then observe how it has been transformed. In Bartlett's experiments, the first subject would read some exotic story, and after 15–30 minutes try to reproduce it as precisely as possible; then the second subject would read this reproduction and write down the next version, and so on. A chain of reproductions led to most remarkable transformations of the original story. At first, Bartlett gave his subjects an Indian folk story filled with supernatural events and mysterious occurrences that followed one another without any clear logic or causation. After a series of transformations, the story became much more coherent, the supernatural elements disappeared, and causal links were added. The story turned into an ordered, rationalized account of events—an account of a sort much more typical of the Western culture in which Bartlett's subjects lived.

In another set of experiments, Bartlett used a passage from Wallace's *Darwinism*, containing specialized biological terminology and a somewhat involved argument with several logical steps. Bartlett discovered the following:

> . . . educated subjects are likely to understand and remember astonishingly little of any scientific subject concerning which they have been given no specialized training. Here . . . statements are promptly converted into their opposite, the title disappears, proper names are changed. Between the original and the final reproduction there is no obvious link of connection.[41]

Again, a series of reproductions gradually transformed the original text into something more comprehensible to the experimental subjects, retaining the details that made sense to them and omitting or distorting everything else. From his experiments with Russian Scandal, Bartlett concluded that remembering was determined by "schemes"—cultural patterns characteristic of a larger group.

In 1947 Wiener again visited Bartlett, now one of the leading British psychologists, in his Cambridge laboratory. At that time, Wiener was actively working out a conceptual synthesis of wartime studies of control and communication processes in organisms and machines under the umbrella of cybernetics. Laying the foundation of cyberspeak, a universal language for men and machines, Wiener established parallels between the functioning of servomechanisms (analog control devices used in anti-aircraft gunnery) and the purposeful behavior of pilots and gunners: in both cases, the goal was being reached by means of a feedback mechanism. Wiener quickly translated Bartlett's current work into cyberspeak and described it in *Cybernetics* (1948) as a study of "the human element in control processes."[42] Thus Russian Scandal, in the form of Bartlett's experiments, found a place within cybernetics.

In the Soviet Union, on the other hand, the newborn cybernetics itself became the subject of a *true* Russian scandal. In Soviet public discourse in the early years of the Cold War, cybernetics acquired the literally scandalous reputation of a "modish pseudo-science." Figuratively, the mechanism of a

Soviet anti-cybernetics campaign resembled the game Russian Scandal, for it involved profound discursive transformations similar to those in Bartlett's experiments. Although this campaign has been traditionally viewed as an intentional product of human agency (in this case, the Party and government agencies), I interpret it here as a sequence of events spontaneously generated by self-perpetuating Cold War propaganda discourse.

Postwar Ideological Campaigns as Rituals

As was discussed in chapter 1, in the late 1940s and the early 1950s several waves of fierce ideological disputes spread across Soviet science, most strongly affecting such fields as philosophy, logic, mathematics, physics, astronomy, chemistry, genetics, linguistics, political economy, and physiology. These disputes, often referred to as "ideological campaigns," followed one another with machine-like regularity, which suggested an underlying pattern. Contemporaries often assumed that these campaigns originated at the top of the Party hierarchy and then spread downward according to a carefully planned scenario. Historical accounts not infrequently trailed such perceptions and described postwar ideological campaigns as carefully planned, directed from above, and executed in accordance with Party guidelines:

> Stalinist ideological campaigns usually unfolded by the same scheme. The groundwork is laid by individual remarks by the Boss and his trusted lieutenants, which signal, in a comparatively restrained form, the upcoming operation. At the second stage, meetings at the Central Committee are held, where activists assemble and listen to instructive pogrom-like speeches, initiated and occasionally personally delivered by Stalin. Then a decision follows, in the form of a resolution of the Central Committee, its Secretariat, or its Organizational Bureau, or as an editorial in *Pravda*. On this basis, a witch-hunt starts, involving vociferous denunciation in the press, a search for new enemies, administrative measures, and occasionally purges and arrests. Then follows a certain retreat, the campaign is wrapped up, and some merciful gestures ensue, which can emanate only from the Boss himself. His role as a charismatic leader is timely to step in and stand up for the unjustly persecuted; sometimes he can even punish some of the overzealous executors. A period of calm follows, preparing ground for a new campaign.[43]

The regular patterns of the ideological campaigns were often taken as signs of thorough planning, and chronological sequences of events were often interpreted as causal chains. Such perceptions, based on the belief in the omnipotence of the Soviet state and the omniscience of its leaders, fit well with the "totalitarian model" of Soviet society. This model assumed a fundamental conflict between Party authorities and scientists, and the campaigns, accordingly, were often interpreted as persistent attempts on the part of Party authorities to subdue the intelligentsia and to place Soviet science and culture firmly under Party control.[44]

Recent studies, based on newly available archival materials, have seriously questioned this top-down, purely confrontational model. New scholarship suggests that postwar campaigns often lacked coherence and coordination. Campaign participants displayed more independence and initiative than one would expect from mere diligent executors of the supreme will. The authorities, in turn, often seemed to be acting on contingency rather than executing some master plan. The relationships between the Party apparatus and the scientific community in the late Stalinist period can hardly be seen as purely antagonistic; indeed, some historians even describe these relationships as "symbiotic," with scientists often appealing to Party authorities for support and the Party leaders using scientific controversies to political ends.[45] Instead of open conflict, Party authorities and scientists were often engaged in negotiations, maneuvering, and skillful manipulation of the ongoing campaigns to their own ends.

The active involvement of Party organs and Stalin himself in postwar ideological campaigns in Soviet science, although quite conspicuous, was limited to a few chosen instances. Only in a handful of disciplines (biology, linguistics, political economy) did high-ranking Party officials explicitly approve "ideologically correct" scientific theories. Every new campaign, however, spread quickly over the entire range of scientific disciplines, and scientists in all fields had to realign themselves in a new direction. How to apply the Party line on linguistics, say, to mathematics, was by no means clear, and this left much leeway for campaign activists. Not infrequently, rank-and-file campaign participants misinterpreted the "signals from above," intentionally or not, and conducted the campaigns according to their own understanding.

In the same way the Party exploited the Lysenko affair for Cold War propaganda, campaign activists often brought their own agendas into Stalinist campaigns. National campaigns opened a wonderful opportunity for some critics to settle scores with their personal foes. Campaign activists took great initiative in picking and choosing heroes and villains in their own fields, nominating candidates for the leading roles of ideologically acceptable native Russian "founding fathers" and their irreconcilable opponents:

preachers of Western pseudo-science. It was always possible to trace some unfortunate Western ancestry in their opponents' theoretical foundations and, by cleverly manipulating ideological labels, to bring a charge of "reactionary, idealistic pseudo-science." Aiming at an individual (usually in the academic establishment), critics could easily find a suitable ideological label to stick to the victim. "Pseudo-sciences" could thus be chosen specifically to fit particular targets.[46]

A radical displacement of the academic elite, similar to Lysenko's triumph over the Soviet biological establishment, occurred, however, only in a few academic fields. In most disciplines, despite much ideological noise, minimal administrative measures followed. The vociferous campaign against Linus Pauling and George Wheland's resonance theory of valence in chemistry serves as a telling example. Campaign activists condemned this theory on philosophical grounds as "mechanistic" (for allegedly reducing chemical phenomena to physical and mathematical laws) and well as "idealistic" (for its supposedly speculative character). They duly contrasted it with the structural theory of the Russian "founding father" Aleksandr Butlerov. The most vocal critics, however, gained no personal career advantage. There were no significant changes in the Soviet chemical establishment. Several of the exposed adherents of the resonance theory lost their jobs or were suspended from teaching temporarily, while one of the most prominent targets of criticism, the chemist Aleksandr Nesmeianov, after admitting his "errors," was promoted to president of the Academy of Sciences. The historian Aleksandr Pechenkin argues that this campaign was nothing more than a ritual fulfillment of minimal ideological obligations on the part of Soviet chemists: "The theory of resonance and its adepts among Soviet scientists . . . played the role of a sacrificial lamb. Soviet scientists performed a ritual dance, sacrificed one particular theory, without which, they believed, they could manage, and returned to their daily business."[47]

Postwar ideological campaigns often had different origins, varying intensities, and unexpected final outcomes, but they usually displayed great similarities on the level of ceremony and ritual. The historian Alexei Kojevnikov has argued that such familiar campaign rituals as "consideration" (*obsuzhdenie*, a discussion of the conclusions to be drawn by the practitioners of a particular scientific discipline from an authoritative ideological decree), "disputation" (*diskussiia*, the debating of controversial scientific issues in an ideological language), and "criticism and self-criticism" (ritual denunciation of opponents and admission of ideological mistakes) were borrowed by Soviet scientists from the canonical repertoire of "games of intraparty democracy."[48] Although most campaigns followed the same ritual pattern, their actual outcome often depended on the participants' ability to play such "games" well and to divert the ongoing campaign to their own ends.

Rather than being victimized by Bolshevik ideology, scientists often skillfully manipulated ideological discourse and performed campaign rituals to earn support and funding from their Party patrons. The historian Nikolai Krementsov argues that the campaign against "reactionary and idealistic science" that followed Lysenko's 1948 address was "largely initiated, orchestrated, and fine-tuned by the leadership of the scientific community itself" in their effort to elude Party control and maintain their own authority while paying no more than lip service to Party rhetoric.[49] Clever science administrators often turned ideological campaign events into a means of extracting more resources from the authorities under the banner of strengthening the "right trend" in science. Resorting to the same metaphor as Pechinkin, Krementsov notes that "like rain dances performed by a shaman in the desert, the 'dances' performed by the scientific community aimed to call forth a golden rain from above and to avoid 'the punishing hand' of angry gods."[50] Instead of uniformly strengthening the Party's control over science, postwar ideological campaigns thus often served scientists' own purposes, which could significantly differ from the goals of the Party leaders.

As an extreme case of the local transformation of a central goal, one could imagine an inadvertent campaign, never planned at the top, that emerged on a large scale as the unexpected outcome of a local initiative or misinterpretation. Contemporary observers, from whom the operations of the Party apparatus were hidden, tended to assume that each campaign was directed by the authorities and thus would not be able to distinguish an epiphenomenal campaign from a real one. A series of public attacks on cybernetics in the first half of the 1950s, usually listed among Party-sponsored ideological campaigns, seem to fall precisely under the rubric of epiphenomena.

The Cybernetics "Scandal"

A brief enumeration of public attacks on cybernetics in the Soviet press in the first half of the 1950s gives the impression of a well-orchestrated campaign. In May of 1950 *Literaturnaia gazeta*, without naming cybernetics, published an article that listed Norbert Wiener among the "charlatans and obscurantists, whom capitalists substitute for genuine scientists," and called the computer hype in the United States a "giant-scale campaign of mass delusion of ordinary people."[51] In 1951, in a book published by the Institute of Philosophy, cybernetics was placed under the rubric of "semantic idealism," and cyberneticians were branded "semanticists-cannibals."[52] In April of 1952 *Literaturnaia gazeta* attacked cybernetics in an article unambiguously titled "Cybernetics—a 'Science' of Obscurantists."[53] After that, a flood of anti-cybernetics articles filled newspapers, scholarly journals, and popular magazines. The content of these articles was reflected in their titles: "Cybernetics—An American Pseudo-Science," "The Science of Modern Slaveholders," "Cybernetics—A Pseudo-Science of Machines, Animals, Men and Society," and so on.[54] In 1954 cybernetics was defined as a "reactionary pseudo-science" and "a form of modern mechanicism" in a new edition of the *Short Philosophical Dictionary*, a standard ideological reference for Soviet scholars.[55] Historians have often assumed that these attacks reflected an officially sanctioned negative attitude toward cybernetics as a doctrine fundamentally incompatible with dogmatic Soviet philosophy of science.[56] I would argue, however, that the conflict between cybernetics and Soviet philosophy was a product, not the cause, of the anti-cybernetics campaign. The Soviet image of American cybernetics as an ideological enemy was shaped by the Cold War, and one should look for the origins of this campaign in that context rather than in any essential features of cybernetics itself.

Soon after the formation of NATO in April of 1949 the Cold Warriors in the Soviet Union stepped up their propaganda campaign. In the spring of 1949 the Party Central Committee's Department of Propaganda and Agitation (Agitprop) drafted a "Plan for the Intensification of Anti-American Propaganda in the Near Future," which was soon approved by the Central Committee Secretariat. The plan outlined a number of measures intended "to expose the aggressive plans of American imperialism," "to debunk the myths of American propaganda about the 'thriving' of America," and "to show the decay of bourgeois culture and morals" in the United States. The plan directed all major Soviet newspapers (including *Pravda* and *Literaturnaia gazeta*) and several popular literary magazines to publish on a regular basis articles on such topics as "The Degeneration of Culture in the USA," "Cosmopolitanism in the Service of American Reaction," "The Crisis of Education in the USA," and "Science in the

Service of American Monopolies." No specific scientific discipline, except economics, was mentioned; such details were left entirely to the discretion of campaign participants.[57]

Soviet journalists began a frantic search for stories that could fit the assigned topics. Reading contemporary sensational reports in the American press about the advent of automatic digital computers and the impending era of "thinking machines" gave Boris Agapov, the science editor of *Literaturnaia gazeta*, an idea. On 4 May 1950 *Literaturnaia gazeta* published his article "Mark III, a Calculator," which thoroughly ridiculed the computer hype in the United States. One memoirist has described Agapov as a "self-educated man, without any formal background in science and technology, but with fine intuition, good literary style, and an enormous capacity for mastering tasks."[58] All these characteristics proved very handy in this case. In his article, Agapov confessed right away that he did not know much about Norbert Wiener, "except for the fact that he is already old (although still brisk), very fleshy, and smokes cigars." Nevertheless, this scarce information sufficed for the imaginative journalist to make up all the rest. In a good literary style, Agapov mocked American businessmen who "love information as American patients love patented pills," and dismissed the idea of using computers for processing economic information. He scoffed at the "sweet dream" of American capitalists to replace class-conscious workers with obedient robots. He regarded as laughable the "fantasies" of the Western military about replacing soldiers in the battlefield with "thinking machines." Commenting on a cartoon depicting a computer dressed in a military uniform on the cover of *Time*, he concluded: "It becomes immediately clear in whose service is employed this 'hero of the week,' this sensational machine, as well as all of science and technology in America!"[59] Although Agapov did not use the word *cybernetics*, his article had a profound impact on the reception of cybernetics in the Soviet Union. After its publication, the Lenin State Library in Moscow—the largest book collection in the Soviet Union—reportedly withdrew Wiener's *Cybernetics* from circulation.[60] This article thus played a critical discursive role, for it was evidently taken as a "signal" of the official negative attitude toward cybernetics.

Cybernetics made its first, and rather unfortunate, appearance in Soviet public discourse during this anti-American propaganda campaign. In 1951, as a weighty contribution to this campaign, the Institute of Philosophy published a collection of papers under the characteristic title *Against the Philosophizing Henchmen of American and English Imperialism*. One of the papers, authored by the psychologist Mikhail Iaroshevskii, was devoted to criticism of "semantic idealism." This term acquired currency in the vociferous campaign that followed Stalin's condemnation of the Marrist school in linguistics. Among the numerous sins Stalin had ascribed to the Marrists was "the overvaluation of semantics and its misuse," which supposedly "led to idealism."[61] The label "semantic idealism" quickly traveled from anti-Marrist discourse into anti-American propaganda, and Soviet critics soon attacked Western semanticists for their supposed idealistic philosophical errors. Party bureaucrats began listing "semanticism" in their documents among other "reactionary philosophical 'shabby schools'" that American imperialism employed to "'justify' cosmopolitanism and American aggressive plans for attaining world hegemony."[62] Having first learned about cybernetics from a Western journal on semantics, Iaroshevskii unhesitatingly placed cybernetics under the rubric of "semantic idealism." He charged that Wiener shared with such "semantic obscurantists" as Bertrand Russell, Alfred North Whitehead, and Rudolf Carnap the reductionist claim that "thinking is nothing else than operations with signs." Wiener's well-known remark about the market devaluation of the human brain as a result of automation, which was apparently meant as a liberal critique of market values, was interpreted by Iaroshevskii as a misanthropic escapade. "From this fantastic idea," he wrote imaginatively, "semanticists-cannibals derive the conclusion that a larger part of humanity must be exterminated."[63]

In the meantime, trying perhaps to distance their work from the ideologically suspect speculations about "thinking machines," two Soviet computer specialists sent *Literaturnaia gazeta* a manuscript criticizing American cybernetics. The authors, Ekaterina Shkabara and Lev Dashevskii, were members of a small group working secretly in Kiev on the construction of the Small Electronic Calculating Machine (MESM, standing for Malaia elektronnaia schetnaia mashina), the first Soviet computer. They wrote that cybernetic analogies between the human brain and the computer were reactionary and methodologically harmful, and that cyberneticians were reducing humans to the status of a mechanical automaton.[64] The physiologist Petr Anokhin, who was asked to review their manuscript, joined in their ideological criticism of cybernetics. Mixing anti-American and patriotic ideological stereotypes in the best tradition of newspeak, he dismissed Western-born cybernetics as reactionary nonsense and, in the same breath, claimed national priority in elaborating the very same ideas. He condemned cyberneticians' attempts to apply feedback models to the complex phenomena of higher nervous activity "in a crude mechanistic fashion." Cybernetics, he wrote, "stands on a flawed methodological foundation, contains a whole series of illiterate neurological assumptions and speculations, and serves the reactionary goals of a capitalist society." As Pavlov's former student, Anokhin expertly concluded that the Pavlovian doctrine was "absolutely incompatible with the mechanistic ideas of this absurd 'teaching.'" At the same time, he proudly noted that cyclical regulatory mechanisms and the idea of feedback had already been thoroughly studied in the Russian school of physiology, particularly in the work of the nineteenth-century physiologist Ivan Sechenov. However, Anokhin was cautious not to attract attention to his own use of feedback models back in the 1930s. In the end, he suggested that *Literaturnaia gazeta* ask a physiologist to write a comprehensive article critical of "specific cybernetic statements that contradict the common sense and the materialist understanding of the functioning of the human brain."[65] The *Literaturnaia gazeta* staff asked Iaroshevskii, who enjoyed the reputation of a leading critic of American psychology, to write a popular critique of cybernetics.

On 5 April 1952 Iaroshevskii's article—the first Soviet publication devoted specifically to criticism of cybernetics—appeared in *Literaturnaia gazeta*. Iaroshevskii reiterated Agapov's earlier criticism of Western computing, seeing behind it merely the intentions to replace a proletarian striker with a robot and to replace a human pilot who refused to bomb civilians with an "indifferent metallic monster"—only this time placing all this under the rubric of cybernetics. Iaroshevskii also added some philosophical errors to the list of cybernetics' sins. Since he had earlier associated cybernetics with "semantic idealism," he easily fitted his critique of cybernetics into the ongoing campaign against "reactionary, idealistic trends" in Western science. As an example of "idealism," Iaroshevskii cited the method of checking calculations by running them simultaneously on two independent computing devices—a practice, he alleged, that derived the criterion of truth from computation alone. He concluded that cybernetics was a "modish pseudo-theory," fabricated by "philosophizing ignoramuses" and "utterly hostile to the people and to science."[66]

The authors of subsequent anti-cybernetics publications clearly interpreted Iaroshevskii's article as a signal to start a full-blown anti-cybernetics campaign. Yet far from being a trusted Party spokesman carrying out the important task of articulating the official line toward cybernetics, Iaroshevskii was a persecuted scholar scrambling to rescue his reputation after serious charges of ideological deviations. A non-Party member with an ominous "spot" in his biography, Iaroshevskii was in a particularly vulnerable position and presented an easy target in the wave of postwar ideological campaigns.[67] After the publication of Stalin's critique of Marrism, the Institute of Philosophy was conducting an urgent search for open and hidden followers of this condemned doctrine, and in December of 1950 Iaroshevskii, then a researcher at the institute, was named among the malicious adherents of Marrism.[68] With the start of a campaign against "cosmopolitanism," Iaroshevskii, who was Jewish, had a strong reason to fear the worst. Deciding to leave Moscow for a quieter location where ideological battles were not so intense, he moved to the Soviet Central Asian republic of Tadzhikistan, taking up a teaching position there.[69] Party activists at the Institute of Philosophy proudly attributed his departure to their uncompromising struggle against Marrism.[70] It was in his semi-exile in Tadzhikistan that Iaroshevskii wrote his anti-cybernetics article for *Literaturnaia gazeta*, hoping perhaps to repair his tainted image.

Iaroshevskii did not receive any benefits from his ideologically correct critique; on the contrary, he nearly ended up in jail because of this publication. His mistake was that he followed the clichés of Cold War propaganda much too closely. After castigating the military applications of computers in the West, he glorified the positive achievements of Soviet computing. On the basis of Shkabara and Dashevskii's manuscript, he concluded that Soviet computing was not falling behind the West. "Soviet scientists constantly improve mathematical machines," he wrote. "Among the greatest achievements in this field are automatic, high-speed electronic calculating machines of Soviet design."[71] Unfortunately, he was much closer to the truth than he realized. Soon after his article came out, Iaroshevskii was urgently summoned to Moscow and interrogated by the secret police about his sources of information on Soviet computing, a top state secret at that time. He was released only after declaring that his statement was "a play of imagination."[72] While Iaroshevskii was privately suffering the consequences of his careless remark, the public criticism of cybernetics in *Literaturnaia gazeta* acquired a significance of its own and had a fate independent of its author's. The view of cybernetics as a "pseudo-science," reproduced in several central newspapers and magazines, became all but official.

Attacks against cybernetics were consonant with Cold War propaganda, and Party ideologues, by encouraging this propaganda in general, indirectly helped turn these attacks into a large-scale campaign. In September of 1952 the Department of Philosophy and Legal Studies of the Central Committee submitted a report to Secretary Mikhail Suslov which concluded that the situation on the "ideological front" remained unsatisfactory: Soviet philosophers had not managed to deliver "crushing blows to the representatives of the Anglo-American center of philosophical reaction" or to expose the links between American imperialism and such philosophical schools as pragmatism, voluntarism, irrationalism, and semanticism.[73] The department urged the journal *Voprosy filosofii* to increase the number of publications critical of Western philosophy and sociology and proposed setting up a special sector for the criticism of contemporary bourgeois philosophy at the Institute of Philosophy. The institute immediately organized such a sector, with thirteen full-time professional critics of contemporary bourgeois philosophy and sociology.[74] The institute's academic council adopted a resolution that called upon Soviet philosophers "to criticize and destroy all reactionary philosophical trends that appear in bourgeois countries under new, modish names and spread the propaganda of a new war."[75] Neither in Party documents nor in the directives of the leaders of the Institute of Philosophy was cybernetics mentioned; apparently it was not yet viewed as a major "reactionary philosophical trend."

Cybernetics—a new and modish name indeed—had already been linked in the press to imperialist reaction, and before long Soviet critics turned it into a full-fledged "philosophical trend." When researchers at the Institute of Philosophy conducted a comprehensive search for appropriate targets of criticism, they quickly discovered cybernetics. The new sector elaborated a thorough plan aimed at exposing "the pseudoscientific and reactionary character of such trends in contemporary bourgeois philosophy as instrumentalism, semanticism, neothomism, existentialism, cybernetics, and others."[76] In particular, the sector pledged to prepare several popular brochures criticizing "phenomenalism, cybernetics, existentialism, and the like."[77] In the prospectus of a textbook on the critique of contemporary bourgeois philosophy and sociology, cybernetics was listed seventeenth among "idealistic schools."[78] Cybernetics was now classified as a philosophical theory stuck firmly between phenomenalism and existentialism.

Following Party directives, the journal *Voprosy filosofii* opened a special rubric, "Critique of Bourgeois Ideology." Its editor-in-chief, Fedor Konstantinov, proclaimed: "What we need is a combative spirit in order not [merely] to attack individual [Western] philosophers but also to have an organized onslaught. We must have a plan for the entire year in which it is specified whom will we attack this year, so that we do not criticize passing individuals who have no significance in the West, but instead criticize those who have influence."[79] Among the first items to appear under the new rubric was "Whom Does Cybernetics Serve?" Published under the pseudonym "Materialist" in the October 1953 issue, this article took the philosophical critique of cybernetics to a new level. Not only were the cyberneticians said to "cling to the decrepit remnants of idealistic philosophy"; they were also accused of "mechanicism," for they allegedly reduced the activity of the human brain "to a mechanical connection and to signaling."[80] Cybernetics thus appeared to deviate from dialectical materialism, the official Soviet philosophy of science, in two opposite directions: toward idealism and toward mechanicism. "Materialist" resolved this seeming contradiction in a truly dialectical manner, explaining that cybernetics was based, in fact, on mechanicism "transformed into idealism."[81] Having exhausted the available repertoire of philosophical accusations, the author turned to the clichés of anti-imperialist propaganda. From the fact that the first automatic digital computers in the United States were constructed for the Department of Defense, "Materialist" concluded: "This is the god whom cybernetics serves!"[82]

After cybernetics was attacked in the main academic philosophical journal, closely supervised by the Central Committee, criticism of cybernetics became a standard element of Soviet public discourse on American science. Other journals, newspapers, and magazines hastily jumped on the anti-cybernetics bandwagon; they too had to fulfill their quotas for articles critical of American science in the service of imperialist ideology. The more anti-cybernetics articles were published, the more obvious it seemed that the campaign reflected an officially sanctioned attitude, and the more critics hurried to join the chorus. Each critic carried criticism one step further, gradually inflating the significance of cybernetics until it was seen as a full embodiment of imperialist ideology.

Serial Reproduction of Criticism

As in Bartlett's serial reproduction experiments, Soviet critics' accounts of cybernetics departed further and further from Wiener's original and acquired more and more features introduced by the zealous critics themselves. Their knowledge of cybernetics was not very good to begin with. Agapov's boasting of his ignorance about Wiener's work was not bravado but a frank confession. Agapov's case was not an exception, but the rule. Virtually all Soviet critics of cybernetics—mostly philosophers and psychologists with little mathematical or engineering training—based their critiques on second- or third-hand accounts. Agapov's critique was based almost entirely on the 23 January 1950 issue of *Time*; Iaroshevskii's sources were limited to Shkabara and Dashevskii's manuscript and a single article in a 1949 issue of *Etc.: A Review of General Semantics*. In a letter to the leading Soviet cybernetics specialist, Aleksei Liapunov, Dashevskii later confessed to being an "absolute ignoramus in this field" and asked for a bibliography.[83] None of the Soviet critics, except for "Materialist," quoted directly from Wiener's *Cybernetics*; the most common sources were Wiener's sensationalistic interviews, philosophers' bold speculations, and journalists' enthusiastic reports in popular Western magazines. Even "Materialist" (this pseudonym apparently belonged to psychologist Viktor Kolbanovskii) reportedly had not read *Cybernetics* and may have borrowed his only quotation from a secondary source.[84] This is not, after all, surprising: after the publication of Agapov's article, even the opponents of cybernetics could not check out Wiener's book from a library!

The physical or conceptual inaccessibility of primary sources did not bother Soviet critics; they extracted all the information they needed from previous critical reviews and then merely applied the general rules of ideological discourse to develop their argument. The author of an anti-cybernetics article in *Medical Worker* borrowed the entire content of his article from Agapov's and Iaroshevskii's publications in *Literaturnaia gazeta*, adding only a couple of general anti-imperialist invectives of his own.[85] No knowledge of cybernetics was evidently needed for participating in the anti-cybernetics campaign; regular reading of the Soviet press provided a sufficient repertoire of critical arguments. During Khrushchev's political "thaw," the leaders of the Academy of Sciences frankly admitted in their 1956 annual report to the Central Committee that Soviet philosophical discourse had perpetuated "the practice of writing books exclusively or almost exclusively on the basis of other books already written on the same or similar subject."[86]

The anti-cybernetics campaign thus acquired its own dynamics, with each author adding a few new strokes to the gruesome image of cybernetics. Soviet critics' ignorance of the content of cybernetics only helped them unleash their imagination. Skillfully manipulating a handful of quotations from Wiener taken out of context, the critics stretched cybernetics' clothes to make them fit their ideological straw man. Lenin's "classical" critique of the "idealistic" philosophical speculations about the alleged "disappearance of matter" in the equations of relativity physics in the early twentieth century was thoroughly imitated during the anti-cybernetics campaign. Soviet critics similarly claimed that cyberneticians reduced biological and sociological laws to "pure" mathematical formulas and equations, which opened a way to "idealistic speculations."[87] The critics "creatively" translated Wiener's vague statement that "information is information, not matter or energy" into a brassy claim that "'information' has nothing to do with matter or consciousness," and concluded that cybernetics marched along a "straight road toward open idealism and religion."[88]

Another allegation of philosophical error—that of "mechanicism"—was to some extent based on the interplay of the words *mechanistic* and *mechanical*. "On the basis of mechanistic principles," one critic wrote, "in the United States recently emerged the pseudo-science of cybernetics, which promises to build perfect mechanical robots."[89] The critics labeled any man-machine analogies mechanistic and reductionist. "*No* mechanical model can be identified with any biological process, especially with higher nervous activity," they maintained.[90] As an ideologically correct alternative, they put forward the "materialist" physiological doctrine of the Russian scientist Ivan Pavlov, utterly neglecting the fact that Pavlov's theory of conditional reflexes had been modeled on the telephone switchboard—a much more primitive technological metaphor than the cybernetic analogies with the servomechanism and the computer.[91]

The critics were evidently more concerned with making a propaganda show than with conducting a serious philosophical analysis of original cybernetic works, which most of them had not even read. They took full advantage of the rhetorical "elasticity" of dialectical materialism to turn it against cybernetics. "Materialist," for example, cited the First Law of

Dialectics, which postulated the transition of quantity into quality, to argue that the cybernetic parallels between people and machines ignored "the qualitative difference between a living organism and a machine."[92] This law, however, could in principle be interpreted in favor of cybernetics. The dialectical "qualitative leap" might be seen not as an insurmountable barrier but as a connecting ladder, not as a "gap" but as a "bridge." Indeed, just a few years later, during the post-Stalinist "thaw," other Soviet philosophers would argue that the First Law actually provided a bridge between mind and machine, since the growing complexity of computers could lead to a qualitative change in their intelligent functions. As Loren Graham has keenly observed, "the basic 'laws' underlying this argument—that of the transition of quantity into quality—could be used in favor of the notion of thinking machines as well as against it."[93] But the participants in the anti-cybernetics campaign, who had already been determined to "criticize and destroy" cybernetics as a breed of bourgeois ideology, naturally preferred the interpretation that gave them the greater critical leverage.

Soviet critics also labeled cybernetics a "reactionary imperialist utopia" aimed at rationalization and legitimization of capitalism.[94] They constructed this "utopia" out of Wiener's gloomy prophecy of a "second industrial revolution," produced by cybernetic automation, that would carry with it "great possibilities for good and for evil" and could result in mass unemployment. "The skilled scientist and the skilled administrator may survive" this revolution, he wrote, explaining the social dangers of automation to labor leaders, but "the average human being of mediocre attainments or less has nothing to sell that it is worth anyone's money to buy."[95] The critics read this passage not as a warning but as an enthusiastic proclamation of the main goal of the entire cybernetic enterprise: "The process of production realized without workers, only with machines controlled by the gigantic brain of the computer! No strikes or strike movements, and moreover no revolutionary insurrections! Machines instead of the brain, machines without people! What an enticing perspective for capitalism!"[96] The critics charged that contemporary cyberneticians "go out of their way to lower man, to show that man can be completely—and should be—replaced by machine."[97] While some critics castigated Wiener for his alleged enthusiasm, others denounced his skepticism. Ignoring his view that automation still had "great possibilities for good," they concluded that cyberneticians served the interests of capitalists by playing down the benefits that computers and automation could bring to the entire society.

Further, Soviet critics branded cyberneticians "contemporary technocrats" who had allegedly conspired "to step in, 'scientifically' explain, and 'fix' the 'malfunctioning' of society."[98] Cyberneticians were accused of making "a fetish of technology" and pretending that acute social problems could be "solved with exact mathematical formulas."[99] The critics again turned Wiener's views completely upside down. In his writings, Wiener repeatedly attacked the "excessive optimism" among American social scientists about the prospects of applying cybernetic methods to anthropology, sociology, and economics. He argued that irregular social processes were not amenable to the same type of mathematical analysis as regular neurophysiological processes. "In the social sciences we have to deal with short statistical runs," he explained, "[and we cannot] be sure that a considerable part of what we observe is not an artifact of our own creation."[100] Again, while some critics denounced Wiener as a technocrat, others censured him for not extending cybernetic models into the social sciences. The latter charged that Wiener denied the objective nature of laws of social development and therefore "objectively oppose[d] any kind of social science."[101] "The sociological theory of cyberneticians is directed against historical materialism," they concluded.[102]

Like any ideological discourse assembled from prefabricated components, the anti-cybernetics campaign was insensitive to its inner contradictions. Producing a typical oxymoron, the critics branded cybernetics "not only an ideological weapon of imperialist reaction but also a tool for accomplishing its aggressive military plans," referring to the use of computers and servomechanisms in the construction of remotely controlled, automated, electronic weapons.[103] It was not entirely clear how a worthless pseudo-science—an expression of obscurantist, reactionary ideology—could assist in the construction of working weapons. To enlarge the significance of cybernetics as a formidable ideological enemy, the critics gave it credit for all military applications of computing and control engineering in the West. True, as was argued in the previous chapter, cybernetics was informed by wartime research projects and embodied some elements of military thinking, patterns of encoded communication, and principles of command and control. Yet cybernetics for Wiener and his associates was a civilian enterprise; their cybernetic ideas largely affected the life sciences and the social sciences, while the military benefited mostly from Wiener's earlier mathematical work. Cybernetics could be seen, therefore, as a product, rather than a driving force, of American military research on control and communication. Soviet critics also ignored, or perhaps were not aware of, Wiener's open pacifist stand, which he had taken after Hiroshima.[104]

Soviet political discourse was gradually shaping the image of American cybernetics according to the standard set of anti-American propaganda clichés, and the inherent contradictions of this discourse became imprinted on that image. American cybernetics was portrayed as both "idealistic" and "mechanistic," as "utopian" and "dystopian," "technocratic" and "pessimistic," as a "pseudo-science," and as a dangerous weapon of military aggression. The inconsistencies of the anti-cybernetics discourse and the critics' indifference toward these inconsistencies suggest that the anti-cybernetics campaign was not driven by some "inherent incompatibility" of cybernetics with dialectical materialism. Instead, this conflict was rhetorically constructed after cybernetics had become a target of anti-American propaganda.

The Soviet campaign against cybernetics developed along the familiar lines of Russian Scandal. As in Bartlett's experiment on serial reproduction of Wallace's *Darwinism*, a complex scientific subject was boiled down to a set of distorted statements with missing logical links. The end product similarly conformed to a pre-established "scheme" or cultural pattern—in this case, the ideological principles of Cold War propaganda. The critics' ignorance about cybernetics only made it easier to stick new derogatory labels on this barely known subject. Neither quantum mechanics, nor relativity theory, nor the chemical theory of resonance, nor even "formal genetics" was entitled by Soviet critics to such a rich diversity of charges. They gradually transformed the image of cybernetics into a comprehensive enemy ideology, elaborated largely by the critics themselves according to the clichés of anti-American propaganda.

Ironically, Iaroshevskii's offhand remark in his 1952 article in *Literaturnaia gazeta* that among the greatest achievements of modern computing were "automatic, high-speed electronic calculating machines of Soviet design" was absolutely correct. The MESM, the first stored-program electronic digital computer in Europe, was already working in Kiev, and two more machines were under construction in Moscow. Their very existence, however, was strictly classified, for they were developed almost exclusively for defense purposes. While the "soldiers of the ideological front" were dismissing cybernetics as a "modish pseudo-science," the actual soldiers in uniform took Western military research on computing and control very seriously. They realized that the Soviet Union was falling behind the West in a crucially important field of military technology, and they aspired to close the gap as quickly as possible.

Computers as "Mathematical Machines" of the Cold War

The fact that Western electronic digital computing and cybernetics had originated in the military sector played a remarkable dual role in a Soviet context. On the one hand, it served as a pretext for the ideological condemnation of cybernetics as a tool of imperialism; on the other, it attracted the serious attention of the Soviet military toward cybernetics and to the use of computers as control devices. As a result, the anti-cybernetics campaign in the open Soviet press unfolded in parallel with growing Party and government support for top-secret computer and automated-control projects in the defense sector. Iurii Zhdanov, the former head of the Science Department of the Central Committee in 1951–1953, recalled in his memoirs: "While Stalin spoke against modern genetics, he never opposed cybernetics. On the contrary, in connection with the space enterprise every effort was made to advance computer technology. In particular, our Department had an assignment to help Academician S. A. Lebedev with the construction of the first machines of the BESM type. And that was done."[105]

The Cold War clearly determined the chief priority for postwar Soviet science: "not only to overtake but to surpass in the near future the achievements of science beyond the borders of our country."[106] This was formulated by Stalin himself in February of 1946. After Hiroshima, Stalin realized the military and political significance of nuclear weapons and ordered urgent measures to close the nuclear gap. In August of 1945 two extraordinary agencies were created to oversee the Soviet atomic project: political supervision was trusted to the First Special Committee under the State Defense Committee, while daily management was assigned to the First Chief Directorate under the Council of People's Commissars. The Special Committee included leading defense scientists and members of the ruling Politburo.[107] The same management model was used in two other top-priority defense programs: rocketry and radar. In May of 1946 the USSR

Council of Ministers (as the Soviet government was now called) set up the Special Committee on Jet Propulsion Technology (also known as the Second Special Committee), which directed the development of ballistic missiles.[108] In June of 1947 the Council of Ministers created the Committee on Radiolocation (the Third Special Committee) to oversee the construction of anti-missile defense systems. The Second and the Third Chief Directorate, respectively, were created for the daily management of the last two projects. All three large-scale crash programs were strategic undertakings inspired by the Cold War, and in all three cases the Soviets set the goal of catching up with the Americans in the shortest possible time.[109]

The three Special Committees were given virtually unlimited funding and the authority to draw material resources and manpower from any sector of the economy. The Finance Ministry officials complained in vain about the "uncontrollable financing" of the First Chief Directorate, which did not even bother to submit its accounts and reports to the Ministry.[110] At the end of 1948 the First Directorate directly employed 55,000 people (not including construction workers) and let research contracts to more than 100 institutions.[111]

The first reports about electronic stored-program digital computers designed and built in Britain and the United States in the 1940s attracted great attention from Soviet mathematicians and physicists working on defense projects that required large amounts of computation. In 1946 the Soviet mathematical journal *Uspekhi matematicheskikh nauk* [*Advances in Mathematical Sciences*] devoted a special double issue to "mathematical machinery." The issue featured two survey articles and two translations from English, including Vannevar Bush's account of his differential analyzer.[112] Although this first publication was devoted exclusively to analog computing, a brief note about Western advances in electronic digital computing soon appeared.[113] A complete outline of the stored-program concept was extracted from open Western sources and published in *Uspekhi* in 1949.[114]

Additional information on Western computing may have come through intelligence channels. Collecting information on American military scientific and technological projects, along with political espionage, was one of the chief priorities of Soviet foreign intelligence. One former intelligence officer attached to the Soviet consulate in New York has recently revealed that in 1942–1946 he obtained more than 20,000 pages of classified documents from seven agents working at the plants and laboratories of RCA, Western Electric, Westinghouse, General Electric, and two aircraft companies. The documents contained scientific and technical information on radar, sonar, computers, and other electronic equipment.[115]

Soviet defense researchers quickly translated their practical need for powerful computing machinery into the political language of "overtaking and surpassing" Western science. In October of 1947 Mikhail Lavrent'ev—the leading expert in mathematical modeling of explosions—appealed to a general meeting of the Soviet Academy of Sciences to close the gap in the area of computing, or "machine mathematics," where the Soviet Union risked falling behind the West. "While in the basic branches of mathematics [in the last 30 years] we have caught up with and in many areas even surpassed Western mathematics," he said, "with respect to machine mathematics we must exert much greater efforts." Lavrent'ev proposed the foundation of a specialized institute for applied mathematics and computer technology.[116]

The primary task of the first computers in a socialist country turned out to be exactly the same as in the capitalist world: calculations for the military. All three crash programs—nuclear weapons, ballistic missiles, and anti-missile defense—required large amounts of computation, and defense researchers took full advantage of their power to expropriate all resources necessary for the fulfillment of their top-priority tasks. In September of 1948, responding to Lavrent'ev's call, the Academy of Sciences established the Institute of Precise Mechanics and Computer Technology in Moscow, which immediately received three high-priority government assignments: creating a wireless system of automatic control of long-range missiles, designing an electric simulator of the long-range missile, and compiling ballistic tables for anti-aircraft fire.[117] The institute also rendered computing services to various military organizations on the basis of individual contracts—for example, performing calculations used in the construction of targeting systems for bomber aviation.[118]

At first, military needs were served by analog computing devices, and the first experiments with electronic digital computing occurred only on the periphery of Soviet computing. The first Soviet stored-program digital computer, the MESM, was completed in December of 1951 by a small group of twelve designers and fifteen technicians led by Sergei Lebedev, director of the Institute of Electrical Engineering in Kiev. The MESM was the first operating stored-program computer in continental Europe.[119] The president of the Ukrainian Academy of Sciences, a biologist who was not involved in defense research, did not see much use for computers and gave little help to Lebedev's group.[120] In early 1952 the Automatic Computing Machine M-1, built by an even smaller group of nine designers and technicians, was put into operation in the Laboratory of Electrical Systems of the Energy Institute in Moscow. As one participant recalled, this project was carried out "semi-legally," almost as a private "hobby" of the laboratory's head, Isaak Bruk.[121]

Soviet digital computing left the stage of pilot projects and received serious institutional and material support only when the leading mathematicians working on defense projects concluded that large-scale, high-speed calculations would be performed more efficiently by digital computers. Mikhail Lavrent'ev, who sponsored Lebedev's project, reportedly sent a personal letter to Stalin emphasizing the importance of digital computing for national defense and calling for more intensive efforts in this field.[122] Lebedev, in turn, submitted an official report, emphasizing the potential applications of the MESM for solving problems of nuclear physics, jet propulsion, radiolocation, and the aviation industry. The high speed and precision of calculations on electronic computers, he argued, made it possible to construct devices that would guide missiles by continuous calculation and real-time correction of their trajectories.[123] As soon as the MESM became operational, it was immediately used to perform urgent military calculations for the Applied Mathematics Division of the Soviet Academy of Sciences in Moscow, an institution created specifically to provide mathematical support for the design of nuclear weapons and ballistic missiles.[124]

As soon as the Soviet leaders became convinced that digital computing was vitally important for national defense, they took decisive measures to support it. In January of 1950 the government authorized two independent projects to build large high-speed digital computers: one (known as the BESM) at the Institute of Precise Mechanics and Computer Technology of the Academy of Sciences, the other (known as the STRELA) at Special Design Bureau 245 of the Ministry of Machine Building and Instrument Construction.[125] By Stalin's demand, the decree specified the names of chief designers personally responsible for each project. The Academy named Lavrent'ev and Lebedev, while the Ministry appointed Mikhail Lesechko and Iurii Bazilevskii to the task.[126] In March of 1950 the Academy appointed

Figure 3.1
Sergei Lebedev. Courtesy of Natal'ia Liapunova.

Figure 3.2
Engineers Lev Dashevskii (sitting) and Solomon Pogrebinskii at the MESM computer. From B. Malinovskii, *Istoriia vychislitel'noi tekhniki v litsakh* (Kiev: Kit, 1995).

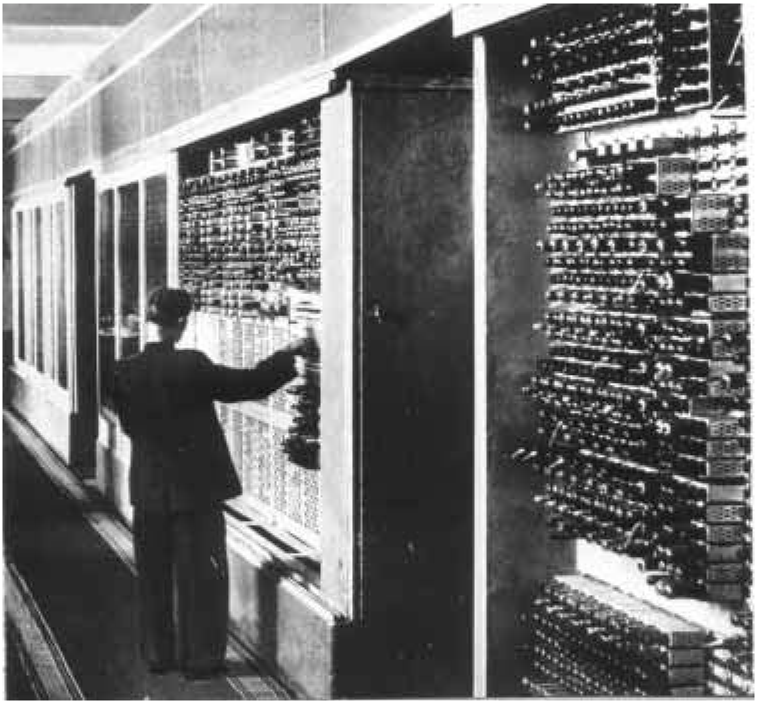

Figure 3.3
The BESM computer. From Malinovskii, *Istoriia vychislitel'noi tekhniki v litsakh*.

Lavrent'ev director of the Institute of Computer Technology; soon the institute received funding for 100 new positions.[127] Lavrent'ev immediately invited Lebedev to set up a laboratory at the institute with a staff of more than 70 people to design a new digital computer.[128] In October of 1951 the institute moved to a large new building, a rare luxury in postwar Moscow. At its inception in 1948, the entire Institute of Computer Technology consisted of only 60 people; by April of 1952, when Iaroshevskii's anti-cybernetics article appeared in *Literaturnaia gazeta*, Lebedev's laboratory alone had a staff of almost 150.[129] Most crucially, Lavrent'ev's long-time political patron, Nikita Khrushchev, just appointed the head of the Moscow city Party organization, promised the institute his personal support.[130]

As soon as the STRELA and the BESM were completed, they were employed to perform urgent calculations for the defense researchers. In 1953 the first STRELA was transferred to the Applied Mathematics

Division to help solve problems of nuclear physics and missile ballistics. In 1955 the first BESM was installed at the specially organized Computation Center of the Academy of Sciences, where it also largely served military clients. While defense scientists used their influence to gain priority access to the first computers, computer specialists were exploiting their connections among the military to obtain vital support on the early stages of Soviet electronic digital computing.

The atomic project, the highest on the government's priority list, became the most avid consumer of computer power and the most powerful source of support for early computer initiatives. The mathematician Sergei Sobolev, Deputy Director of the Institute of Atomic Energy and in charge of the mathematical calculations for the construction of nuclear weapons, became a major patron of Soviet digital computing. Constantly seeking computer power for the growing volume of calculations, he rented computer time, helped obtain scarce electronic parts for new machines, and even commissioned the construction of new computers. Under his patronage, the Institute of Atomic Energy built its own small digital computer and put it into operation in November of 1953.[131] In the meantime, in 1952–53, atomic researchers became the first users of the M-1 computer at the Energy Institute. Using his unlimited authority to procure any necessary resources, Sobolev helped obtain for M-1 urgently needed vacuum tubes, then in extremely short supply.[132] In 1952 Sobolev became the chairman of the Department of Computational Mathematics at Moscow State University; he also headed the University Computation Center, where he sponsored the construction of an original ternary-system electronic digital computer.[133]

The ballistic missile program was another major client of Soviet digital computing. In 1952 the specialized journal *Voprosy raketnoi tekhniki* [*Problems of Rocket Technology*] published the Russian translation of a detailed Western review of recent advances in electronic digital computing.[134] That publication served as a basic text in the first course on computer programming at Moscow State University.[135] The first problem solved on the M-2, Bruk's second electronic computer, was the calculation of thermodynamic and gasodynamic parameters for missile design.[136] The method of running important calculations simultaneously at different computation facilities, which Iaroshevskii branded "idealistic," was routinely employed by the Soviet military in the design of nuclear weapons and ballistic missiles to ensure the correctness of crucial calculations. Missile trajectories,

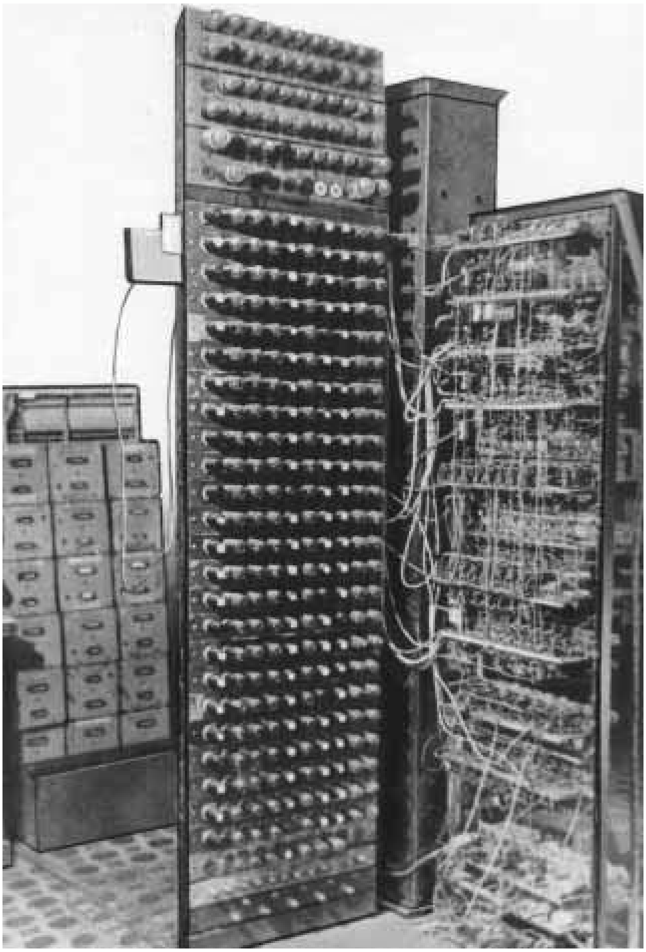

Figure 3.4
The Automatic Computing Machine M-1. From Malinovskii, *Istoriia vychislitel'noi tekhniki v litsakh*.

for example, were computed independently at the Applied Mathematics Division of the Academy of Sciences and at Experimental Design Bureau 1 of the Ministry of Armament.[137]

The third major military crash program—anti-missile defense—also pushed digital computer developments forward. In the 1940s, the Deputy Chairman of the Council on Radiolocation, Engineer Vice-Admiral Aksel' Berg, regularly received intelligence information on American radioelectronics, which he appreciated greatly.[138] In 1953 Berg was appointed the Deputy Minister of Defense in charge of radar. He asked his subordinate Anatolii Kitov to prepare a report on Western computing.[139] Kitov's upbeat report had profound consequences. The Ministry of Defense quickly organized three large military computation facilities: Computation Center 1, the Navy Computation Center, and the Air Force Computation Center. All three were equipped with the first serially produced STRELA computers.[140] Design Bureau 1 of the Third Chief Directorate, which designed the anti-missile defense complex around Moscow, also received one of the first STRELA computers, thanks to the active role of the bureau's chief engineer, who headed the state commission that tested the STRELA.[141] Among the first problems solved on that computer was the calculation of the dependency of the target-destruction probability on the detonation efficiency of fragmentation warheads.[142] For field tests of its anti-missile defense system, Design Bureau 1 commissioned a specialized computer from the Academy Institute of Precise Mechanics and Computer Technology. This computer, the M-40, was completed in 1958. Together with another model, the M-50, it was used to control the first Soviet anti-missile defense system.[143] Bruk's M-2 computer was also employed to make calculations for a military research institute under Berg's command.[144]

While Soviet "soldiers of the ideological front" read about cybernetics in popular Western magazines and developed a principled ideological critique of this "idealistic and reactionary doctrine," Soviet military experts were reading the Western professional literature and drawing significant conclusions about the utility of computers and automatic control devices for the construction of weapons. In July 1953, at the height of the anti-cybernetics campaign in the Soviet press, Dmitrii Panov, then director of the newly established Institute of Scientific Information, submitted to the Central Committee a secret report titled On Small-Size Electronic Computing Devices and Their Application for Control Purposes. Here he did not talk of cybernetics as a "pseudo-science" or "a weapon of imperialist reaction"; instead he adopted a businesslike tone: "From materials published in American journals, it is clear that the USA is conducting extensive work on designing various electronic control devices."[145] Panov then cited several examples of control devices used in American aircraft and anti-aircraft gunnery and flight control; he pointed out that the greater efficiency of the F-86 aircraft over the Soviet MIG-15 demonstrated during the

Korean war might be due to the F-86's on-board automated control system. Soon Panov was appointed Deputy Director of the Institute of Precise Mechanics and Computer Technology.

While the Soviet press vociferously condemned the "abnormal, one-sided" development of American military computing and ridiculed the "fantasies" of robots giving out military orders, the Soviet military tried desperately to catch up with Western developments in computing and military cybernetics. Following the Western lead, Soviet military specialists began looking for means of "optimal control" of military units, and Computation Center 1 began working on automated troop-control systems.[146]

In the 1950s only one ostensibly civilian computer facility was organized. This was the Computation Center of the Academy of Sciences, created by the decree of the USSR Council of Ministers in February of 1955. It was equipped with two large high-speed computers: a STRELA and a BESM. Even those two machines, however, were heavily utilized to perform military calculations.

In September of 1955 the Academy created a special commission to resolve priority disputes over the use of its computing resources by various academic institutions.[147] Even though the commission recommended that at least 20 percent of the total computer time be allocated for the solution of "general" (that is, unclassified) scientific problems, this recommendation was hardly followed.[148] The commission included only leading defense researchers, who often quietly divided the computer time among themselves. Even for military calculations alone, however, computer time was in short supply, and commission members often engaged in bitter disputes with one another. For example, in December of 1955 Mstislav Keldysh, director of the Applied Mathematics Division and member of the commission, submitted a formal letter of disagreement with the commission's decision. He stated that the calculations performed by his Division "have primary importance and are more important than most of the calculations performed at the Computation Center by other organizations." Keldysh claimed that the 140 hours of computer time allocated for the Division in December of 1955 were "clearly insufficient" and requested "at least 50 hours of computer time per week."[149] Such disputes had to be resolved on a higher administrative level, and eventually lists of calculation problems and allocated computer time were reportedly submitted weekly for approval to the Chairman of the Soviet Council of Ministers, Nikolai Bulganin.[150]

Soviet digital computing, boosted by the military demand for large-scale computation, became narrowly focused on military applications. The nuclear weapons researchers (led by Igor' Kurchatov) and the designers of ballistic missiles and spacecraft (supervised by Sergei Korolev) used up almost all the resources of the first Soviet digital computers. The cosmonaut Georgii Grechko has recalled his experience of working on the BESM at the Academy Computation Center in the mid 1950s as follows: "Kurchatov's people used it in the daytime and during the night Korolev's people. And for all the rest of Soviet science: maybe five minutes for the Institute of Theoretical Astronomy, maybe half an hour for the chemical industry."[151] The Soviet view of the computer as a strategic technology, rather than a general-purpose information processor, assigned civilian science applications a subordinate role.

Design organizations built totally different types of computers for the defense and the civilian sectors. For example, the M-20 computer, designed by the Institute of Precise Mechanics and Computer Technology for the nuclear weapons laboratories in Arzamas-16 and Cheliabinsk-60 in 1958, operated at the speed of 20,000 operations per second, while the general-purpose BESM-2 machine, which the institute completed the same year, ran only at 10,000.[152] In 1961 the de facto defense affiliation of the institute was made official: it was transferred from the Academy of Sciences to the State Committee on Radioelectronics, one of the pivotal agencies of the military industrial complex. Only one element of the institute's civilian past, a plaque on the front door asserting the institute's affiliation with the Academy, was preserved. It is still there.

While in the Soviet Union in the early 1950s computer applications were confined to top-secret calculations for the military, in the United States the computer quickly spread from the military sector to the business world. American computer manufacturers and business users reconstructed the computer and turned it from a mere mathematical instrument into an electronic data-processing machine.[153] In the Soviet case, the centralized control over the production and distribution of computers secured a virtual monopoly of the defense sector over computer access. Military and civilian computer applications were separated by another "iron curtain." This separation was indeed a product of the Cold War: it was supported, on the one hand, by the priority of military calculations and, on the other, by ideological suspicion about cybernetics.

The Military Definition of Computing: Technology without Ideology

In September of 1950 Mikhail Lavrent'ev, then director of the Institute of Precise Mechanics and Computer Technology in Moscow, told his subordinates that Soviet computing lagged behind the Americans by 10–15 years. He showed photos of a new high-speed American computer built for military purposes.[154] "Our task is clear," he said:

> Within 5 years we must catch up with foreign countries. . . . We must eliminate the lag in high-speed digital computers. . . . I am confident that our Institute will not betray the trust of the Government and Comrade Stalin, and will overtake and surpass foreign countries.[155]

"Overtaking and surpassing" American computing did not appear to be the only mission of the institute, however. In December of 1952 one of the leaders of the institute's Party organization formulated another responsibility for his colleagues:

> One of the most important tasks of our [Soviet] academic institutions, including our Institute, is the elimination of metaphysics and idealism from science. A deep reconstruction has occurred in the social sciences, physiology, and biology. Metaphysics and idealism in the natural, physical and mathematical sciences cannot be tolerated and must be weeded out.[156]

Presented with such divergent priorities, the institute's researchers now had to figure out a way to catch up with American computing without falling under the spell of alien ideological influences.

Even though cybernetics was labeled in the Soviet press a "pseudoscience," computers were not considered "pseudo-machines." Soviet critics of cybernetics campaign only branded as "idealistic" and "mechanistic" the use of man-machine analogies in the life sciences and the social sciences; they did not at all object to the use of computers for automation and scientific calculations, which were regarded as acceptable "materialistic" applications. The critics even called the invention of a computer a "real scientific and technical achievement" and argued that computers had "great value for the most diverse phases of economic construction."[157] Computers, they claimed, could make "calculations of any degree of complexity in the shortest possible time," being capable of "completely flawless operation and procurement of results."[158] While condemning military uses of computers in the West, Soviet critics enthusiastically praised the power of Soviet computers, which were expected to liberate people from "the 'dirty' mental labor" of complex and tiresome calculations.[159] Soviet "soldiers of the ideological front" presented "machine mathematics" as value neutral: in a bourgeois society, it served imperialist ideology; in a socialist country, it naturally upheld socialist values.

As the anti-cybernetics campaign in the popular press was intensifying, Soviet mathematicians and computer specialists felt growing pressure to dissociate their work from the ideologically deficient cybernetic parallels between people and computers. They adopted the familiar discursive strategy of "de-ideologization," and they drew a sharp line between ideology-laden cybernetics and "ideology-free" computing. In a 1952 secret report on the current state of Soviet computing, Lebedev and Keldysh unequivocally distanced themselves from Western cybernetics: "It should be noted that bourgeois press frequently makes analogies between the functioning of a [computing] machine and the human brain. Such claims are totally absurd."[160] Leaving cybernetics to philosophers for proper criticism and destruction, the authors portrayed computing as a purely technical enterprise, which, they argued, must be guided by the "overtake and surpass" principle. Contrasting Soviet efforts (only three large digital computers under construction) with American attainments (eleven large computers under operation and ten more under construction), they called for urgent measures to close the computing gap.

To facilitate the acquisition of information about Western computing, the Soviets launched a series of translations of Western computer literature—a step that was potentially problematic for obvious ideological reasons. Soviet scientific publishing, in addition to the technical mission of disseminating knowledge, had the political mission of disseminating the right ideology. In a 1954 report, the chief physics editor of the Foreign Literature Publishing House emphasized precisely this political mission:

> We must remember that we are dealing with foreign authors, in whose work one often encounters alien ideology. This ideology is expressed in the publication of books that carry propaganda of idealistic pseudo-scientific theories, in a systematic suppression of the works of Soviet scientists, or in the diminution of their significance. In editorial prefaces and comments we must protect the Soviet reader from alien ideology and defend the priority of Soviet scientists.[161]

To meet these requirements, Soviet computer specialists supplied their translations with a clever introduction that condemned ideological "errors" while rescuing the supposedly "non-ideological" technical content. As a result, Western computer literature passed the censor relatively easily; for most publications, the interval between the original Western edition and the Russian translation did not exceed 2 years.[162] To be on the safe side, Soviet editors also cut out from the original all ideologically dubious passages. The editor's preface to the 1952 translation of the American book *High-Speed Computing Devices* openly stated that all "dubious analogies between people and machines in the spirit of pseudo-scientific statements of 'cyberneticians'" in the Russian version had been eliminated.[163] The editor of the Russian translation of Claude Shannon's paper "Mathematical Theory of Communication" even renamed the work "The Statistical Theory of Electrical Signal Transmission" to remove any trace of anthropomorphic analogies. The editor's preface read as follows:

> The terminology of the statistical theory of electrical signal transmission and a number of its concepts are utilized by some foreign mathematicians and engineers in their speculations related to the notorious "cybernetics." For example, building upon superficial, surface analogies and vague, ambiguous terms and concepts, Wiener, Goldman, and others attempt to transfer the rules of radio communication to biological and psychological phenomena, to speak of the "channel capacity" of the human brain, and so on. Naturally, such attempts to give cybernetics a scientistic look with the help of terms and concepts borrowed from another field do not make cybernetics a science; it remains a pseudo-science, produced by science reactionaries and philosophizing ignoramuses, the prisoners of idealism and metaphysics. At the same time, the notorious exercises of philosophizing pseudo-scientists cast a shadow on the statistical theory of electrical signal transmission with noise—a theory whose results and conclusions have great scientific and practical importance.[164]

Concerned with the ideological image of their work, Soviet computer specialists chose their terminology very carefully. For example, in 1951 Lebedev was advised by his colleague to avoid the term "logical operations";[165] logical reasoning was viewed as a domain of philosophy, not of computing. Such suspect terms as *information*, *computer memory*, and *servomechanism* were usually replaced with the neutral technical terms *data*, *storage*, and *tracking device*. One Soviet scientist explained: "If we replace the word *memory* with *storage* or *depot*, that would not allow for the analogies drawn by Wiener and others, but these words would still have the same meaning."[166] Behind these rhetorical feats lay the discursive strategy of "de-ideologization": computing and information theory were portrayed as purely technical tools with no connection to the ideology-laden biological and social sciences.

Unlike Western technical publications on computing, popular books filled with philosophical and sociological speculations had little chance of being translated. The publication of the Russian translation of Wiener's *Cybernetics* was delayed for 10 years.[167] Only a handful of English-language copies of *Cybernetics* circulated within a small circle of Soviet control engineers and computer specialists. One of these copies of Wiener's book was read in Isaak Bruk's Laboratory of Electrical Systems at the Energy Institute in Moscow, and several researchers from this laboratory began to think of computers in broader terms. In particular, the engineer Mikhail Kartsev, who took an active part in the construction of the M-1 and M-2 computers, felt that military tasks were too narrow for these machines. In 1954, at a discussion of cybernetics at the institute, he boldly stated: "We are interested not so much in the military applications of mathematical machines or, more generally, new technical devices, but in their wider applications."[168] His colleague Nikolai Matiukhin, who led the construction of the M-1, pointed specifically to economics as a very promising field for computer applications. Citing business uses of computers in the United States, he argued that "in our country, such issues must be raised much more sharply. In a socialist society, . . . the mechanization of planning with the assistance of computers can and should be pursued to the largest extent possible."[169] The merciless logic of the military demands on Soviet computing, however, turned the careers of the two men in a different direction from what they envisioned. In late 1957 Kartsev was appointed to lead the construction of the M-4, a specialized control computer for radar systems, and its more advanced version, M-4M, which remained in production until 1985. He later became the chief designer of a multi-processor supercomputer for an early warning system, and he spent the rest of his career in military computing.[170] Also in 1957, Matiukhin joined a group working on the Soviet version of SAGE, an air defense system supported by a geographically distributed computer network, and rose to become the chief designer of numerous computers and networks for national defense.[171] The first Soviet attempts to apply computers to economic planning occurred only in the late 1950s, when Bruk's laboratory, transformed into the Institute of Electronic Control Machines under the State Economic Council, began working on the M-5, a specialized computer for economic applications. Kartsev initially led the M-5 project, but soon he was forced to abandon it to concentrate on the higher-priority M-4 computer.[172]

Figure 3.5
The M-4M computer. From Malinovskii, *Istoriia vychislitel'noi tekhniki v litsakh*.

Civilian computer applications were deterred not only by the heavy militarization of computing, the scarcity of computer time, and the ideological controversy around cybernetics but also, and even more effectively, by the wall of silence and the barriers of clearance requirements around the early Soviet computers. In the paranoid atmosphere of the Cold War, the cloud of secrecy surrounding military computing not only concealed Soviet computers from the enemy; it also created serious internal obstacles for the development of Soviet computing.

Soviet Computers: A State Secret or a "Display Technology"?

The Cold War imposed contradictory demands on Soviet scientists and engineers. They were supposed to hide significant domestic scientific and technological accomplishments from the enemy, especially if those innovations were related to national defense. Yet they were also encouraged to show off their achievements as a matter of national prestige and as proof of the superiority of the Soviet political system. Soviet computing was thus torn between the tendency toward pervasive secrecy and the ideological urge to exploit the political "display value" of computers.[173]

Cold War security concerns imposed severe limits on any discussion of Soviet computing in the open press. Even publishing basic textbooks on computing became a challenging task. In 1949 the chairman of the Department of Computing Machines and Devices at the Moscow Mechanical Institute, Fedor Maiorov, submitted to the publisher a manuscript of *The Electronic Calculating Solving Devices*, the first Soviet textbook on electronic computers. But the Glavlit, the government agency responsible for the preservation of state secrets in the press, refused to permit its publication. After 2 years of fruitless struggle, Maiorov appealed to the Science Department of the Party Central Committee. He explained that his book was based entirely on materials already published in open Soviet and foreign literature. "Keeping in mind the necessity of strict preservation of state secrets," he wrote, "I avoided any descriptions of the specific designs of devices produced in the USSR, any indications of the types of devices used, or their parameters." Even though the type had been set and the proofs were ready, the Glavlit held up publication, possibly in connection with the confiscation of another reference book on a similar subject. "Fearing that something might happen," Maiorov complained, "they refuse to publish my book too."[174] The Science Department sent an inquiry to the Ministry of Machine Building and Instrument Construction; the Ministry conceded that this book could be published, but only by the Military Publishing House and as a classified publication. The Party authorities accepted the Ministry's verdict.[175]

The Ministry's insistence on secrecy restrictions may have been triggered by the ongoing competition between the Ministry and the Academy of Sciences. Since 1950 the two agencies pursued separate projects in designing a large high-speed electronic digital computer, and the prize—launching a serial production—would go to the one that finished first. Any meaningful cooperation between the Academy Institute of Precise Mechanics and Computer Technology and Ministry Special Design Bureau 245 was hindered by the tendency not to share important technical information. As late as 1955 one of the institute's engineers complained: "We know more about foreign scientific research than about the domestic one [at the Bureau]."[176] It was quite possible that Ministry officials simply used the classification of computer research as a pretext for hiding vital technical details from the rival program.

Frustrated with the information blockade of Soviet computing, the institute's director, Lavrent'ev, made consistent efforts to breach this wall of secrecy. In August of 1951 he sent a letter to the Central Committee complaining about a recent article on computing in a major Soviet newspaper:

> The content of the article creates the wrong impression about the state of computer technology in the Soviet Union. Based on this article, a qualified reader abroad would have to conclude that the Soviet Union is lagging far behind in the field of computing and is presently on the level that the United States reached approximately 10 years ago.[177]

Nevertheless, the Ministry of Machine Building and Instrument Construction chose to continue its policy of secrecy. In September of 1951 Minister Petr Parshin complained to the Glavlit about the excessive coverage of the production of calculating machines by the Ministry in Soviet newspapers, magazines, on TV, radio, and in movie theaters. "All this is objectively aimed at divulging state secrets," he wrote. In particular, Parshin complained about the same newspaper article as did Lavrent'ev, only for the opposite reason: for disclosing too much about Soviet computer technology. Parshin requested severe measures to be taken so that "without the Ministry's knowledge, no material about calculating machines be published in central or local newspapers or magazines, no program be broadcast on radio or TV, and no footage be shown in movie theaters."[178] Such measures were indeed taken.[179]

After Stalin's death, the ensuing transformations in the Party and government apparatus, and the beginning of greater openness in public discourse, the Academy tried again to get some publicity for the institute's computer, the BESM. In July 1954, hoping to prove its superiority over the STRELA, the Academy declassified the existence of the BESM and its basic parameters, and soon it was shown to a delegation from India.[180] The Academy also asked the permission of the Party Central Committee to announce the construction of the BESM in the media.[181] The bureaucratic structures set up during the early years of the Cold War, however, remained firmly in place after Stalin's death, and their missions and procedures had not changed much. Party authorities routinely requested the opinion of the Ministry, which, not surprisingly, voiced strong objections. It insisted that the Academy had no right to declassify its computer; this was the prerogative of a government-appointed special State Commission.[182] The Party authorities again sided with the Ministry, and a public announcement was postponed.

This case suggests, furthermore, that the policy of secrecy pursued by the Soviet state was not solely the product of Soviet isolationist ideology, but could sometimes be induced by interagency rivalry and used as a weapon of bureaucratic competition. The Cold War created political conditions in which government agencies could easily justify and employ excessive secrecy measures to their competitive advantage.

While the Ministry, trying to protect its pet project by pervasive secrecy, exploited the authorities' fear of the potential threat of espionage, the Academy sometimes appealed to another ideological stereotype: national prestige. In December of 1954 Dmitrii Panov, Deputy Director of the Institute of Computer Technology, submitted to the Party Central Committee a report titled On the Question of Classifying the Existence of Electronic Calculating Machines in the USSR. The report itself, naturally, was classified. Panov wrote:

> Presently electronic calculating machines are so widespread and so widely used that their existence in a technologically advanced country is presumed self-evident. To claim that in such a country as the USSR there are no electronic calculating machines would be almost the same as to claim that we do not have railroads or electricity, or that we cannot fly through the air. Under such conditions, to classify the existence of electronic calculating machines in the USSR seems to me not only wrong, but also harmful. No one anywhere would believe that we have no such machines.[183]

In addition, in an ingenious twist of the espionage argument, Panov tried to prove that security restrictions must be lifted. He argued that, because of this policy of secrecy, the Eastern Bloc countries intending to develop their own computer technology would have to solicit help from the West, thus making it easier for Western spies to gain access to their scientific institutions. But Panov's report had little effect, and, at the insistence of the Ministry of Machine Building and Instrument Construction, the Soviet authorities continued to keep silent about Soviet digital computers for almost another full year. The Academy's efforts to lift the veil of secrecy from Soviet computing finally succeeded, however, with the arrival of Khrushchev's political "thaw" in the mid 1950s. The first official announcement that the Soviet Union had built high-speed digital computers was made at the Conference on Electronic Digital Computers and Information Processing in Darmstadt, West Germany, in October of 1955. The Soviet delegation disclosed some of the technical parameters of the BESM and the URAL (a new computer constructed at Special Design Bureau 245).[184] Characteristically, Soviet digital computers were declassified for the foreign audience first; an announcement for the Soviet press came later.

Newspeak and Cyberspeak, Two Languages of the Cold War

The cultural role and the practical uses of computers and cybernetic man-machine metaphors both in the United States and in the Soviet Union were profoundly shaped by the Cold War. The first electronic digital computers in both countries were largely employed for defense. The early reception of cybernetic ideas, however, proved radically different on the two sides of the Iron Curtain.

In the United States, cyberspeak spread widely in both the defense and the business sector. The military found it convenient to "incorporate" soldiers mathematically into the weapons they controlled, while computer manufacturers and business users transformed the computer from a mere mathematical instrument into an electronic data-processing machine. Computers, boosted by their popular image as "giant brains," quickly poured from the military sector into the business world. Cyberspeak proved an efficient vehicle for the American "closed-world" discourse, which reflected ideological stereotypes of the Cold War and conceptualized the political and social world as a closed, computable system subject to manipulation and control.

In the Soviet case, a parallel "closed-world" discourse of the Cold War had a different vehicle—newspeak—and this fostered the initial rejection of cybernetics and the wholesale ideological criticism of man-machine metaphors. Torn between the contradictory demands to "overtake and surpass" American science and to "criticize and destroy" American ideology, Soviet scientists creatively reinterpreted Western theories both scientifically and philosophically, trying to separate their "objective content" from the dispensable ideological "shell." American cybernetics in a Soviet context similarly split into two disconnected entities: a set of useful techniques and technologies (quickly adopted by the military) and an ideological monster (lambasted by the professional "soldiers of the ideological front"). The two incarnations of cybernetics lived separate lives, almost never crossing paths. One hid underground in the top-secret world of military computing and command-and-control systems; the other ran freely across the pages of the central press. Despite their surface differences in ideology, the ardent American cyberneticians and the zealous Soviet critics of cybernetics viewed the world in very similar, confrontational terms.

Ironically, ideological attacks on cybernetics encouraged efforts to "de-ideologize" Soviet computing. Soviet computer specialists had to define the area of appropriate computer applications in such a way that it would not cross ideological barriers. To avoid unwanted associations with controversial American cybernetics, they decided to sacrifice cybernetic "philosophy" to be publicly "criticized and destroyed" and to preserve computing as a purely technical enterprise. This strategy severely limited the field of prospective computer applications. The computer was legitimized in this Soviet context as a giant calculator; its capacities as a data processor for economic and sociological analysis and as a tool for biological research were downplayed to avoid ideological complications.

The ideological barriers were reinforced by military restrictions. The high demands placed on Soviet computing by the three top-priority defense programs—nuclear weapons, ballistic missiles, and anti-missile defense—left little room for civilian applications. At the same time, the tendency toward pervasive military secrecy came into contradiction with the ideological task of exploiting the political "display value" of computers. Rather then being guided by a single principle, the development of Soviet computing was shaped by various attempts to manipulate these diverse priorities. Like its American counterpart, Soviet computing adapted to the military and ideological context of the Cold War, even though the particular configuration of political and economic forces at play was different in each case.

In 1958 an entry on cybernetics finally appeared in the additional volume 51 of *The Great Soviet Encyclopedia*, which contained entries missing from the previous volumes. This article acknowledged Norbert Wiener's pioneering role in the development of cybernetics and effectively legitimized this field in the Soviet Union.[185] The author of this article was none other than Andrei Kolmogorov. A separate article, co-authored by Kolmogorov's student, was devoted to Wiener and his mathematical and cybernetic accomplishments. The change in Kolmogorov's attitude toward cybernetics, from initial rejection to later embrace, indicated a profound political and cultural shift in Soviet science—a shift from Stalinism to the Khrushchev era.

This Page Intentionally Left Blank

4

Cybernetics in Rebellion

There are three kinds of science: natural science, unnatural science (the humanities), and anti-natural science (philosophy).
—attributed to Lev Landau[1]

Soviet Science in Search of a New Language

In March of 1953 the Soviet Union entered a new era. "Stalin had been a god," the historian Boris Kagarlitsky noted, "but the god was dead."[2] After the death of Stalin, various tensions in Soviet leadership and society in general came to surface.[3] The two key posts Stalin had vacated—First Secretary of the Party Central Committee and Chairman of the Council of Ministers—were filled by his chief lieutenants, Nikita Khrushchev and Georgii Malenkov, respectively. Prominent Stalinist hard-liners—Molotov, Kaganovich, and others—were maneuvering between the two. Khrushchev and Malenkov had very different ideas on how to deal with Stalin's legacy. Malenkov promoted relaxation of international tensions, rapid development of consumer industries, and further centralization of the ministerial apparatus. Khrushchev worked to give the Party more control over the implementation of economic policy, built a base among local Party officials, and opposed Malenkov's reforms as premature. The official attitude toward Stalin was a matter of fierce debate among the leadership: Khrushchev was pushing for a public exposure of Stalin's crimes, while others insisted on a more cautious approach. The intense struggle within the post-Stalin leadership and the frequent reshuffling of the central Party apparatus resulted in a crisis of the dominant discourse, whose foundations were suddenly up in the air.

The dissipation of the official Party line into a multiplicity of competing viewpoints left Party bureaucrats perplexed about the boundaries of permissible speech. Liberal intellectuals immediately put a wedge in the crack. In April of 1955, at an April Fools comedy performance before the staff of *Literaturnaia gazeta*, one journalist thoroughly ridiculed the ritual of "self-criticism," one of the most common public rituals of the Stalinist era. After delivering a satiric sketch, he brought a feigned apology to the audience for all the "fallacious and sinful" elements in his sketch, readily admitted his mistakes, and then mockingly criticized his own apology for being insufficiently profound. A high-ranking official who oversaw the performance belatedly complained to the Party Central Committee about this joke, which surely had not been included in the pre-approved scenario of the show.[4] This mockery of canonical discursive rules sharply contrasted with the dead seriousness of Stalinist public rituals.

The old discursive order came under explicit attack in a much-talked-about article titled "On Sincerity in Literature," published in the leading literary journal *Novyi mir* [*The New World*] in December of 1953.[5] Rejecting established canons, the author criticized contemporary Soviet literature for portraying perfect characters in harmonious situations and spoke openly against the "embellishment of life" in such works. He appealed to his fellow writers to tell what they really thought, which was perceived by many as a defiance of the Party's monopoly on thought. Despite the official condemnation (and perhaps partly thanks to it), the article caused a great stir. Many regarded it as "the first manifesto of the post-Stalin liberal intelligentsia."[6] A simple appeal to tell the truth sounded revolutionary in a society accustomed to newspeak, a hypocritical language of politically correct ideological clichés.

Sincerity and *truth* became bywords for the emerging critical movement. The critics could not explicitly attack Stalinism for its crimes yet; instead, they questioned Stalinism as discourse. They boldly challenged the old regime's ritualized way of speaking, which paradoxically combined canonized modes of expression and arbitrary manipulations with meaning. When the orthodox credo was no longer clearly defined and the boundaries of the permissible became blurred, the new generation set itself apart by using fresh and bold language in its attempt to cleanse itself of Stalinist clichés and obtrusive rhetoric.

Many Soviet intellectuals saw in the language of science, particularly mathematics, the sought-after "language of truth." As the Russian cultural historians Petr Vail' and Aleksandr Genis metaphorically put it, "when it turned out that words lied, formulas looked more trustworthy"; "exact knowledge seemed an equivalent of moral truth; an equals sign was put between honesty and mathematics."[7] One prominent linguist has recently recalled: "We were tired of the phraseology of official philosophy. We wanted to deal with precisely described concepts and with notions defined through rigorously described operations."[8] Contemporary writings expressed this attitude most clearly. One law professor wrote: "It is our aspiration that justice, humanism, inevitability, truth and other legal concepts [will be] based on indisputable data and [be] therefore as exact as the concepts of mathematics, physics, and chemistry."[9]

This new spirit of rigorous thinking, logical clarity, and quantitative precision found its embodiment in the cultural image of a new technical device whose existence in the Soviet Union had just been declassified: the electronic digital computer. After the first official announcement in October of 1955, a flurry of articles appeared in Soviet newspapers, magazines, and scholarly journals popularizing this new magic tool for solving hitherto unsolvable problems. No limit to the power of computers was in view. It seemed that computers were able to solve any problem if only it was formulated in the right language: the language of computer algorithms.

In this chapter I explore the transition from Stalinism to the Khrushchev period in Soviet science through the prism of changing Soviet attitudes toward computing and cybernetics. I examine the emerging cybernetics movement as a vehicle of de-Stalinization of Soviet science. This movement put forward the concept of computer-based objectivity as a substitute for the Stalinist principle of Party-mindedness of science. By promoting cyberspeak as a new universal language of science, Soviet cyberneticians challenged the dominant role of newspeak, the vague and manipulative language of Stalinist ideological discourse, and began undermining the discursive basis of the Stalinist regime.

Soviet Computers: Declassified and Deified

With the arrival of Khrushchev's political "thaw" in the mid 1950s, the period of forced isolation of Soviet science and technology from its Western counterpart came to an end. Soviet scholars could now publish abroad, attend international conferences, receive foreign literature, and invite their foreign colleagues to visit. The division into "socialist" and "capitalist" science no longer held; claims were made for the universality of science across political borders. A direct comparison made the gap between the developed countries and the Soviet Union in a number of fields that had been booming in previous years, such as genetics or semiconductor technology, so conspicuous that it could no longer be ignored. Party and government authorities embarked on a course of rapid assimilation of modern Western scientific and technological advances.[10] Catching up with the West in digital computing became one of the top priorities. The first Soviet computers were declassified and almost immediately "deified" in the Soviet press. A new cultural image of the computer was formed: an omniscient, all-powerful, supreme being.

The first sign of political change in the sphere of science and technology was the drastic opening of information floodgates. The small Academy Institute of Scientific Information was transformed into a large All-Union Institute of Scientific and Technical Information staffed with hundreds of researchers and equipped to provide translation and dissemination of most recent reports of scientific and technological developments in the West. "Technical attachés" and "agricultural attachés" were assigned to Soviet embassies to gather relevant information. Foreign scientific and technical literature was translated into Russian and published in large numbers. Since the Soviet Union was not a member of the international Patent Convention, the Soviet government encouraged "assimilative repetition," or simply duplication, of Western technologies.[11]

After information began to flow through the Iron Curtain, some Soviet scientists were also allowed to cross the barrier. In September of 1955 the Soviet Council of Ministers issued a secret resolution titled On the Reorganization of Research Trips of Soviet Specialists Abroad for the Study of Achievements of Foreign Science and Technology and on the Improvement of the Use of Trip Reports in the USSR Ministries and Agencies.[12] Consequently, in March of 1956 the presidium of the Academy of Sciences adopted a resolution titled On Measures Aimed at the Reorganization of International Scientific Contacts and the Improvement of the Use of the Results of Research Trips.[13] Any Soviet specialist going abroad was required to prepare a detailed report of all the innovations seen during the trip and to submit it to several governmental agencies, including the State Committee on New Technology. The presidium issued detailed instructions on how to obtain the permission for a foreign trip, how to invite foreign colleagues, how to obtain the permission to publish an article abroad, and how to maintain correspondence with foreign scholars and scientific institutions.[14] Restrictive as they were, these instructions nevertheless legitimized what had been unthinkable in the late Stalinist period: regular contacts and exchanges between Soviet scientists and their Western colleagues.

Among the first Soviet scientists to take advantage of the new rules were computer specialists. In October of 1955, at the Conference on Electronic Digital Computers and Information Processing, held at the Technische Hochschule in Darmstadt, West Germany, they publicly announced for the first time that the Soviet Union had built several stored-program digital computers. Sergei Lebedev, the chief designer of the BESM computer, and Iurii Bazilevskii, the chief designer at the bureau that had created the URAL computer, arrived in Darmstadt in the evening of 27 October, just after the conference had ended.[15] The organizers hastily arranged a special extra session, at which Lebedev and Bazilevskii gave talks and disclosed some of the technical specifications of their computers. One American participant reported that the BESM compared "favorably in speed and capacity with any American or other European machine other than IBM's NORC (Naval Ordnance Research Calculator)."[16] The BESM was indeed a powerful machine; Lebedev failed to mention, however, that only one copy of the BESM existed, and it was not ready for serial production.

According to Soviet estimates, computing was one of the fields in which the Soviet Union's lag behind the United States was the most pronounced. In January of 1955 Isaak Bruk, a leading computer designer from the Energy Institute, submitted a report on the current state of Soviet "mathematical machinery" in which he argued: "Machines built in this country lag behind foreign ones. The current level of organization and scale of work in the field of mathematical machines and applications of digital technology are such that the gap is not closing but widening every year."[17] In March of 1955 Lebedev's Institute of Precise Mechanics and Computer Technology submitted to the Party Central Committee another report on the current state of Soviet computing. The report drew the authorities' attention to the fact that American computing was rapidly getting ahead of the Soviet computer industry:

> The tempos of development in this field can be compared only to the tempos of development of the jet aircraft and nuclear energy technologies. . . . The gap between the United States and the Soviet Union in the area of digital computers and control devices continues to grow. We are falling behind in the number of machines, as well as in their [technical] parameters. We are also falling behind in production technology and in the application of computing devices, particularly, for military purposes.[18]

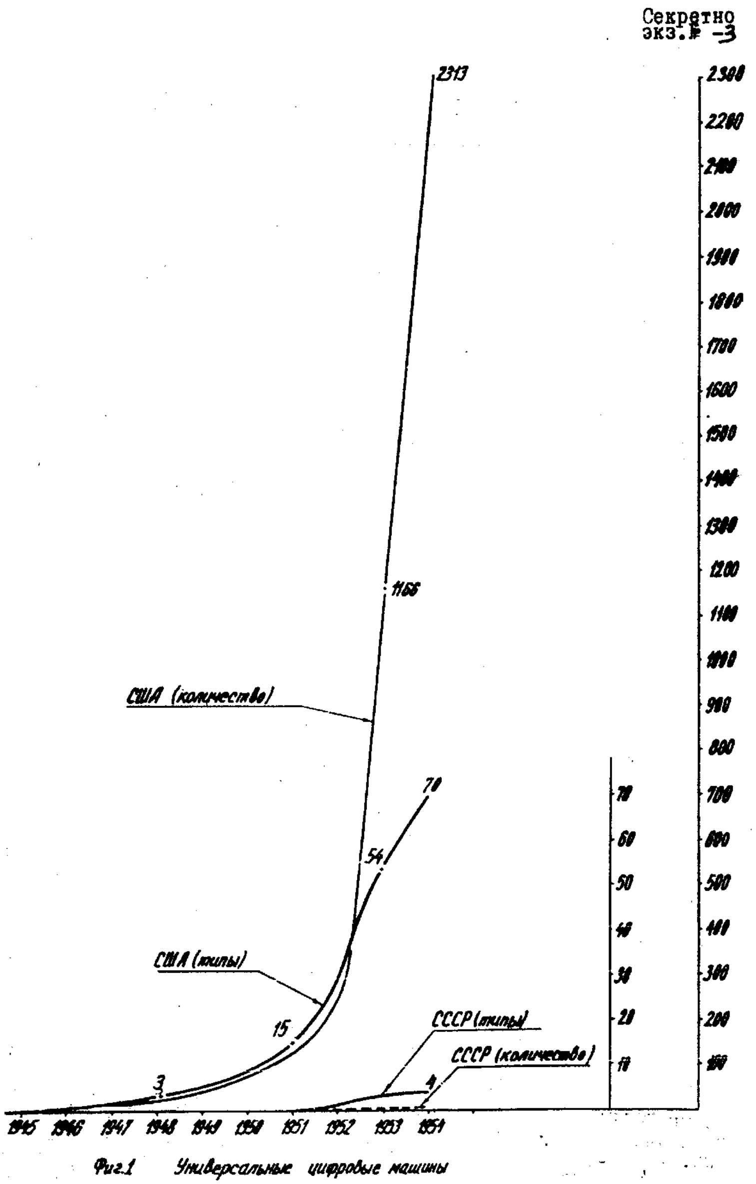

Figure 4.1
The production of universal digital computers in the United States and in the Soviet Union, 1946–1954. From Panov, "Bystrodeistvuiushchie vychislitel'nye mashiny," a secret report of the Institute of Precise Mechanics and Computer Technology to the Party Central Committee, February 1955. The upper curve denotes the number

The Academy of Sciences sent to the Central Committee one report after another, urging greater support for computer research and development in the Academy and the radical expansion of computer production. In particular, the Academy's leaders asked the Central Committee to break the monopoly of the Ministry of Machine and Instrument Construction and to involve another agency, the Ministry of Radio Industry, in computer production.[19]

As a result of these efforts, Party and government authorities began to pay close attention to computing. The Science Department and the Defense Industry Department of the Central Committee received an urgent assignment to study this problem. In April of 1955 the Science Department issued recommendations in support of the Academy's position:

> The industrial branch that produces electronic machines and devices does not sufficiently utilize the achievements of contemporary science and technology; it is lagging behind similar branches abroad. . . . This trend is particularly evident in the field of construction of high-speed calculating devices. . . . We think that the industrial branch that produces electronic machines must be significantly expanded. It is necessary to establish new specialized design bureaus and plants for the design and production of electronic calculating devices.[20]

In July of 1955 the Soviet Council of Ministers decreed that the Academy of Sciences, the Ministry of Machine and Instrument Construction, and the Ministry of Radio Industry must cooperate in the design and construction of a new digital computer. This computer, operating at 20,000 operations per second, was to be completed in the second quarter of 1956.[21]

As soon as the existence of computers was declassified, Soviet scientists and engineers launched a public campaign in support of the rapid development of digital computers. Writing in the Party journal *Kommunist*, the president of the Soviet Academy of Sciences, Aleksandr Nesmeianov, called the creation of high-speed computers a "breakthrough into the next level of science and technology, comparable in its prospects with the atomic breakthrough."[22] Speakers at the conference on Trends in Soviet Mathematical Machine and Instrument Construction, held in Moscow in June of 1956, proclaimed that the computer was "the most advanced achievement of

---

of computers in the United States, the second the number of types of computers in the United States, the third the number of types of computers in the Soviet Union, and the fourth the number of computers in the Soviet Union. Courtesy of Russian State Archive of Contemporary History, Moscow.

modern technology," that computers could perform "calculations that had previously been impossible because of the limited duration of human life," and that "a digital machine can solve problems with practically any required degree of accuracy."[23] In public statements, Soviet scientists emphasized their achievements; Nesmeianov, in particular, boasted that the BESM was "as it seems, a machine with the highest operating speed in Europe."[24] At the same time, in secret memoranda directed to Party and government authorities, Soviet computer specialists continued to emphasize the growing computer gap. The unpublished resolution of the 1956 conference, submitted to the Central Committee, read: "The Soviet Union is further lagging behind the United States and England both in terms of the number and the types of computers produced."[25]

Encouraged by computer specialists, the Soviet media began to shape a cultural image of the computer as an all-powerful magic tool for solving a wide range of problems, from weather forecasting to industrial automation. Articles under such titles as "'Thinking' Machines" and "Bordering on Science Fiction" mushroomed on the pages of newspapers and popular magazines.[26] Journalists quickly dismissed the previous ideological critique of the social consequences of computer-based automation:

> If in the capitalist world the introduction of "thinking" machines means the growth of unemployment, exploitation of workers, and fear of the future, in a socialist society, by freeing people from hard, uninteresting work, machines would provide an opportunity to focus on something lofty and joyful—to think, to create, and, in particular, to create new "thinking" machines.[27]

As "overtaking and surpassing" Western science became the primary goal of Soviet scientists, old ideological taboos rapidly dissolved. If under Stalin the Western origins of a particular scientific theory had been a liability, now the situation was completely reversed. In the post-Stalinist period, the foreign genealogy of such fields of study as cybernetics became an asset rather than a handicap. Soviet critics' ideological suspicion toward the concept of "thinking" machines was no longer relevant; the growing popularity of cybernetics in Western media was now more important. As the historian Alexander Vucinich has observed, "while in the days of Stalin many theoretical ideas were rejected without the benefit of careful scientific scrutiny, now there prevailed a strong tendency to take many Western ideas and research hints seriously even when they appeared to be tenuous or unrealistic."[28]

The Computer as a Paragon of Objectivity

Both its disciplinary culture and its popular press shrouded Soviet digital computing in an aura of unquestionable objectivity commonly associated with mathematics. Computer programming in the Soviet Union emerged as a branch of mathematics: computers were called "mathematical machines," software was termed "mathematical support," the first articles on computing were published in mathematical journals, the first courses were taught at mathematics departments, and among the first Soviet institutions created specifically for complex computer-based calculations was an organization called the Applied Mathematics Division of the Mathematical Institute in Moscow.[29] Computer algorithms were written in the language of mathematical formalisms and were expected to be on the same level of rigor. Seen as a "mathematical machine" rather than a merely technical device, the computer became a symbol of incorruptibility, an honest agent that would never tell a lie.

Computer enthusiasts from various disciplines argued that scientific knowledge was objective only if it could be formalized, converted into computer programs, and tested on a computer. The mathematician Aleksei Liapunov contended that the criterion of our knowledge of a particular control system "must be the possibility of modeling this system in a universal computing machine."[30] The physiologist Nikolai Bernshtein maintained that computer models provided "a demanding and unyielding criterion" of truth:

> In human thinking, there is always certain unconscious arbitrariness, and as a result, an author's ardent belief may prompt him to take the desired for real. But a *model* presented as a program for digital computer or as an electronic analog device would not yield to any attempts to persuade it or to make it change its mind with regard to something incompatible with its structure. The model works strictly in accordance with the objective laws of nature and the equally firmly established laws of mathematics.[31]

The computer-oriented criterion of scientific objectivity was overtly put forward as non-ideological, non-class-oriented, and non-Party-minded. In sharp contrast to the academic discourse of the recent past, the foundation of objectivity was sought in the rigor of mathematical formulas and computer algorithms. Liapunov argued that "quantitative methods, precise language, and precise concepts for representing knowledge" were necessary conditions for the objectivity of scientific knowledge.[32] The precise language of computer algorithms was to replace the vague and manipulative language of ideology-laden academic discourse.

The computer as a paragon of objectivity stood for everything that opposed Stalinist discourse. Computers set a moral example of how to withstand outside pressure and hold onto the truth. Igor' Poletaev, the author of *Signal* (1958), the first popular Soviet book on computers, wrote: "Working with computers nurtures in man precise and rigorous thinking and the ability to give a critical evaluation of his own decisions and actions. One can hardly object to this kind of moral education."[33] He called working with computers "a school of thinking and behavior":

> One cannot communicate with a [computing] machine by hints, half-words, or reticent expressions. The machine does not tolerate contradictions, even inner and hidden ones. The machine does not comprehend vague and fuzzy concepts. When working with the machine, one has to think things through to the very end, without errors and without blunders. The machine forces man to be honest, precise, rigorous, and ready to accept the truth, however unexpected and bitter this truth might be.[34]

Cyberspeak directly challenged newspeak. "Telling the truth" became a motto not only for liberal writers and poets but also for computer specialists. Studying the "forbidden fruit" of cybernetics in the period of political and ideological uncertainty after Stalin's death was not simply a matter of scientific curiosity; it was in essence a political statement. By glorifying the computer as a paragon of objectivity, Soviet scientists implicitly undermined the old Stalinist political and ideological discourse on science. Speaking the language of cybernetics was perceived by many, friends and foes alike, as a defiance of the Stalinist order of things. To do cybernetics became a way to show a recalcitrant spirit. One mathematician, who in the early 1950s organized an informal seminar on cybernetics in Leningrad, told me in a recent interview: "We knew that we were not supposed to study cybernetics, but we always did what we were not supposed to do. We followed the rule: 'If they give you lined paper, write across the lines.'"[35]

The discursive clash between the "ideological language" and the "language of truth" reflected the efforts of the Soviet scientific and engineering community to achieve greater intellectual autonomy. For many years during the rule of Stalin, Soviet scientists and engineers had endured administrative and ideological pressure from Party and government authorities, forced isolation from foreign colleagues, charges of "philosophical deviations," political accusations, purges, arrests, forced labor, and executions. Although such events often resulted from the power struggle among rival groups and their patrons in the Party and in the government, liberal intellectuals personified the enemy in the figure of a "philosopher."

Soviet Philosophy between Scylla and Charybdis

In the Soviet Union, as well as in pre-revolutionary Russia, the first question to ask in a situation of crisis usually was "Who is to blame?" Rather than look for the socioeconomic and political roots of the crisis, critics habitually put the blame on personalities. In the mid 1950s, a similar question was raised: "Who is to blame for the Soviet lag in science and technology?" Scientists insisted that Soviet science suffered from ideological and political interference and put the blame squarely on "philosophers." The "philosophers" were those who attempted to translate scientific knowledge into newspeak (an ideological language saturated with philosophical terminology) and to place political considerations above the scientific truth. The word *philosophy* thus stood here for the entire trend of "ideologization" of Soviet science. By attacking the "philosophers," scientists effectively claimed their own right to judge scientific controversies.

Stalin's death in 1953 and the successful testing of a thermonuclear device later that year both contributed greatly to a radical realignment of power in the Soviet scientific community. Defense physicists gained great prestige and leverage with the authorities, and they used it to full extent. One of the main targets of physicists' attacks became those Soviet philosophers who, in the Stalinist period, had specialized in criticizing Western-born physical theories, such as quantum mechanics and relativity theory, for alleged "idealistic" deviations. Scientists skillfully blamed philosophers for all the shortcomings of Soviet science, while claiming that all Soviet scientific and technological advances occurred despite the philosophers' interference. The physicist Petr Kapitsa claimed that Soviet physicists would not have been able to build an atomic bomb had they followed the advice of dogmatic philosophers, who had tried to use dialectics to "prove" that relativity theory was invalid.[36] In 1954 physicists forced *Voprosy filosofii* to open a discussion on the philosophical problems of physics, and they effectively overturned the previous ideological critique.

Scientists used several reorganizations of the Party and government apparatus that followed Stalin's death to get rid of their most bothersome supervisors and ideological watchdogs. For example, in April of 1953, shortly after Stalin's death, the chief mathematician of the Soviet atomic project, Sergei Sobolev, and two other prominent members of the Soviet Academy of Sciences petitioned the secretary of the Party Central Committee, Nikita Khrushchev, protesting against the activities of the head of the Central Committee Department of Natural and Technical Sciences, Iurii Zhdanov. They accused Zhdanov of intriguing, promoting his personal friends, and creating intolerable working conditions. "As the result of Zhdanov's regime," they wrote, "academicians turned into the smallest people in the Academy of Sciences and became a subject of ridicule."[37] Alluding to the recent notorious anti-cosmopolitanism campaign, they charged that "comrade Zhdanov believes, sincerely or out of ignorance, that by fighting against Jews . . . he truly advances Soviet science."[38] Perhaps in connection with scientists' lobbying, during a reorganization of the Central Committee apparatus, Zhdanov was fired.[39]

The Party apparatus slowly began to adjust its position to the new liberalizing trends of the "thaw." In March of 1954 an editorial in the Party's leading theoretical journal, *Kommunist*, severely criticized Soviet researchers in the social sciences and the humanities, including philosophers, for being "divorced from life."[40] They were urged to engage in "creative discussions" of pressing practical issues, instead of "squeezing life into old formulas." The article also condemned the attempts to establish a monopoly of certain schools in the natural sciences and specifically targeted Lysenko's Academy of Agricultural Sciences.

Using their connections in political and military circles, leading defense scientists began an active campaign for a more radical liberal reform in science policy. In July 1954 Sobolev published an article in the leading Party organ, *Pravda*, in which he emphasized that Soviet scientists and engineers succeeded in such important areas as aviation, atomic physics, and radio technology only because they pursued new lines of research and did not adhere to worn-out dogmas. Using *dogmatism* as a euphemism for the Stalinist legacy in Soviet science, Sobolev specifically attacked the schools of Lysenkoist biology and "Pavlovian" physiology, and called for innovation and freedom of criticism. Using his connections at the top of the Party hierarchy, Sobolev managed to publish his call for reform in the most influential Soviet newspaper, the mouthpiece of official policy, without consulting officials at the Department of Science and Culture of the Central Committee.[41]

Under pressure from natural scientists, the leadership and the direction of *Voprosy filosofii* were changed radically. In early 1955 the newly appointed editor-in-chief of this journal, Mikhail Kammari, was summoned to the Department of Science and Culture and given new instructions. Kammari later told his colleagues at the Institute of Philosophy that his Party supervisors had criticized the editorial board "severely but fairly":

> We accidentally denigrated certain bourgeois scientists, who were not worth much in philosophy but were very prominent figures in their own fields, and we put them under the rubric of reactionaries. By doing that, we were not helping to win over natural scientists to the side of dialectical materialism, we were not moving toward a union of our philosophers with natural scientists; instead, we repelled these scientists. . . . We must overcome the shortcomings revealed in this area.[42]

In June of 1955 the presidium of the Academy of Sciences censured Aleksandr Maksimov, a well-known militant critic of "idealistic" philosophical deviations in quantum mechanics and relativity theory, for his "nihilistic approach to the theory of relativity." The presidium generally condemned the philosophers' practice of "discarding valuable physical results because of their alleged contradictions with dialectical materialism." "As a result," the presidium stated, "there emerged clearly abnormal relations between certain researchers at the Institute [of Philosophy] and natural scientists."[43] Maksimov was soon dismissed as the head of the Department of Philosophical Problems of Natural Science at the Academy Institute of Philosophy. Kammari reported to the Academy authorities: "Comrade Maksimov has committed a number of errors in theoretical issues of physics and proved unable to gather around his department strong academic forces that could solve philosophical questions of contemporary natural science."[44] Maksimov and another fighter against "idealism in physics," Iakov Terletskii, were removed from the editorial board of *Voprosy filosofii*. Scholars with more moderate philosophical leanings were brought to the editorial board, including rector of Leningrad University, the mathematician Aleksandr Aleksandrov, a prominent advocate of the discursive separation between the "objective content" and "philosophical interpretation" of scientific theories. Aleksandrov soon published several articles, in which he accused Maksimov and other militant philosophers of ignorance in both physics and philosophy, and successfully "reconciled" modern physics with dialectical materialism.[45]

When speaking of "philosophy," scientist critics evidently referred not to the basic principles of dialectical materialism, whose emphasis on materialism and objectivity most of them shared, but to the entire ideological discourse shrouded in the philosophical terminology of newspeak. As I argued in chapter 1, in the late Stalinist period this dogmatic version of dialectical materialism turned into an official canon, gradually "calcified," and began to serve as a philosophical cudgel. The scientist critics regarded Soviet philosophical discourse as an embodiment of the spirit of ideological control. The attack on "philosophers" thus served to undermine the dominant role of newspeak in academic discussions.

Not only scientists but also Party authorities had a stake in placing the responsibility for the lags in science and technology on philosophers. Party officials could thus shift the responsibility away from themselves. While reprimanding philosophers, Party functionaries strove to retain their own control over the scientific community. The philosophers thus found themselves between a rock and a hard place: on one hand, scientists blamed them for ideological intrusions, on the other, the Party authorities, who had encouraged such intrusions, now withdrew their support. "To some extent," the historian R. David Gillespie observed, "Soviet philosophers were made the scapegoats for various lags in science and technology."[46]

Voices demanding change also emerged from within the philosophy community. Addressing an audience at the Institute of Philosophy in April of 1956, one such critic said: "Some of our philosophers are concerned with one thing only: how to steer between Scylla and Charybdis so that, on one hand, one could not accuse them of being time-servers, and on the other, one could not accuse them of detachment from life."[47] This critic was Ernest Kolman, who believed that an alliance between dialectical materialism and cybernetics was the solution.

The Newspeak Defense of Cybernetics

In the autumn of 1940 a journal of the Soviet Academy of Sciences published an article titled "Is It Possible to Prove or Disprove Mendelism by Mathematical and Statistical Methods?" ("Mendelism" was a derogatory label the Lysenkoites attached to classical genetics, which they portrayed as a faddish "-ism" based on the works of Gregor Mendel.) Using standard newspeak techniques, the author of this article argued that biological laws could not be proved or disproved by mathematical or statistical means, but only "on the basis of biology" (meaning Lysenkoist biology, which did not require any mathematical processing of experimental data). To invalidate the use of mathematics in the life sciences, the author skillfully invoked the sacred authority of Engels and Lenin, who had postulated a hierarchy of the so-called "forms of movement of matter": from mechanical on the bottom to biological in the middle to social on the top. "According to Engels and Lenin," the author claimed, "the higher the form of movement, the more difficult it is to apply to it the mathematical method and the less effective is this method for the perception of reality."[48]

Fifteen years later, in the summer of 1955, *Voprosy filosofii* published an article titled "What Is Cybernetics?" The author of this article argued that the mathematical apparatus of cybernetics was fully applicable to a wide range of physiological, psychological, and social processes, and similarly invoked the authority of the Marxist classics, only this time for the opposite cause: to reaffirm the power of mathematics to analyze complex biological and social phenomena. "Why can quantitative methods give positive results in every other science but not in psychology?" asked the author rhetorically. Citing Marx's 1878 letter to Engels, he added: "Did not Marx himself put the question of a mathematical investigation of the most complex regularities, the regularities of economic and social phenomena?"[49] The juxtaposition of these two quotes not only suggests that the legacy of Marxism-Leninism supplied an infinitely rich reservoir of appropriate quotations for an experienced author; it also indicates a very significant shift in Soviet public discourse on the role of mathematics in the life sciences and the social sciences. After playing a subordinate role as an ideologically suspicious exercise in abstract speculation under Stalin, mathematics became a powerful instrument and even a methodological guide for these sciences in the Khrushchev years. Comparing these two quotations becomes all the more interesting when one discovers that both articles were written by the same person: the philosopher Ernest Kolman.

The turbulent biography of Ernest Kolman (1892–1979) in many respects paralleled the tortuous paths of Soviet philosophy.[50] Kolman was born into a Czech-Jewish family in Prague. In 1913 he graduated from Prague University, specializing in mathematics. He fought against the Russian troops in World War I and was taken prisoner; after the Russian Revolution, he stayed in Russia and joined the Bolshevik Party. In 1918–1923 he worked as a Party functionary in the Red Army and the Communist International and was twice sent to Germany on confidential

Figure 4.2
Ernest Kolman. From Ilizarov, "Ernest Kol'man, Nikita Khrushchev i IIET."

missions to instigate the "world revolution." In 1923 Kolman was assigned to the Party apparatus in Moscow, where he quickly assumed the role of an ideological watchdog in the scientific community. His duties at this time included being a member of the editorial board of the journal *Under the Banner of Marxism* (1929–1943), director of the Natural Science Institute of Red Professors (1931), member of the presidium of the Communist Academy (1931–1936), head of the Science Department of the Moscow City Party Committee (1936–37), and head of the Department of Dialectical Materialism at the Institute of Philosophy (1939–1945). In all these capacities, Kolman acted as an exemplary militant philosopher, ready to expose any slightest indication of unorthodoxy among scientists. As the historian David Joravsky has put it, Kolman was "one of the most savage Stalinists on the front of science and technology."[51]

With his background in mathematics, Kolman searched for ideological heresy most actively in the mathematical and physical sciences. In 1931, jumping on the bandwagon of the ongoing campaign against "wreckers" and "saboteurs" in Soviet industry, he published an article titled "Wrecking in Science." Kolman labeled mathematical physics "wrecking" and branded "mathematical abstraction" a weapon of counterrevolution:

> "Matter disappears, only equations remain"—this Leninist description of academic papism in modern physics gives the clue to the understanding of the wrecker's predilection for the mathematization of every science. The wreckers do not dare to say directly that they want to restore capitalism, they have to hide behind a convenient mask. And there is no more impenetrable mask to hide behind than a curtain of mathematical abstraction.[52]

"Mathematics in its general development not only reflects class struggle," Kolman wrote in another article, "but also becomes a weapon in the hands of ruling classes, directly or indirectly serving as a cover for religion and helping these classes to achieve their goal of exploitation."[53] He attacked a number of prominent Soviet physicists and mathematicians, including Iakov Frenkel', Lev Landau, and Dmitrii Egorov, accusing them of idealism, which amounted to a political denunciation. Kolman called for a radical reconstruction of Soviet mathematics to make it the most Party-minded and class-oriented of all sciences.[54] As a member of the Soviet delegation to the Second International Congress of the History of Science in London (1931), Kolman had a secret assignment to spy on the prominent physicist and historian of science Boris Hessen. All the members of this delegation except Kolman were purged.[55]

Like many other militant Marxists and activists of the Cultural Revolution, Kolman did not easily fit into the bureaucratic structures of late Stalinism, and he suffered the consequences. After the end of World War II, Kolman was sent to Prague to work as the head of the Propaganda Department of the Central Committee of the Czechoslovakian Communist Party. In September of 1948 he was arrested, as he later wrote to Khrushchev, for criticizing the current leaders of the Czechoslovakian Communist Party.[56] Luckily for him, these leaders themselves were soon purged, and in March of 1952 Kolman was released and returned to Moscow. In 1952–53 he taught mathematics at the Moscow Automechanical Institute. Kolman asked the head of the Science Department of the Party Central Committee, Iurii Zhdanov, to give him a job at the Academy of Sciences or at Moscow University, but neither of those institutions wanted to hire him.[57] In 1953 Kolman finally got a job at the Academy of Sciences Institute for the History of Science and Technology in Moscow.[58]

In November of 1954 Kolman was invited to give a lecture on philosophical problems of contemporary science at the Academy of Social Sciences, an institution affiliated with the Party Central Committee. Kolman chose to speak on cybernetics, and the audience naturally expected that this well-known critic of Western philosophy and science would vigorously condemn this "rotten ideological commodity." Then something entirely unexpected happened. "An age of tremendous cultural-technical revolution is dawning," Kolman prophesied: "the age of self-regulating machines called upon to take over a part of our mental labor."[59] He summarized the basic ideas of Wiener's *Cybernetics*, emphasized the bright prospects of automation, and concluded: "Cybernetics is tested in practice and has for it an exceptional significance, and therefore it is a huge self-deception to consider it a 'huge mystification.'"[60] Joining the powerful chorus of defense physicists, who chastised philosophers for their ideological criticism of physical theories, Kolman asked a rhetorical question:

> Is it not true that the nihilistic attitude of some of our philosophers toward relativity theory and quantum physics has been harmful, when along with a justifiable criticism of idealistic "deductions" which some bourgeois physicist-philosophers had made, the theories themselves were branded as pseudo-scientific and reactionary?[61]

To take a similar "nihilistic attitude" toward cybernetics, Kolman warned, would be a huge mistake. Kolman later wrote in his memoirs:

> It is easy to imagine how changed the faces of the dogmatists who invited me when . . . in my two-hour lecture, instead of showering cybernetics with curses, I argued its exceptionally progressive nature. . . . They jointly rushed at me. All sorts of epithets were thrown at me: a "mechanist," an "idealist," a "follower of the bourgeois vogue," an "enemy of Pavlov's teaching," and God knows what else.[62]

However unorthodox Kolman's position in the cybernetics controversy may seem, his style of argument was quite orthodox: he was trying to prove that cybernetics was fully compatible with dialectical materialism. Reasoning within the traditional framework of Soviet philosophy, he never questioned the philosopher's right to pass judgment on scientific matters; he only argued that the old judgment was wrong and his own judgment was right. Kolman's defense of cybernetics was built on the same discursive principles and used the same newspeak techniques as the earlier attacks against it, only now the same methods were used to reach the opposite goal.

Both Kolman and the earlier Soviet critics of cybernetics made extensive use of the same general rhetorical techniques of newspeak: *quotation-mongering* (fetching appropriate "authoritative" quotations from Marxist-Leninist classics or from a few canonized scientists) and *label-sticking* (invalidating the opponent's claim by branding it as some kind of a philosophical deviation). As the historian David Holloway has argued, these "techniques of persuasive argumentation" were "symptomatic of the politicization of scientific authority and indicated an appeal to the political leadership, rather than to scientific colleagues, for recognition and approval."[63]

A brief comparison of Kolman's argumentation with the rhetoric of the anti-cybernetics campaign reveals remarkable parallels. Although neither Marx nor Lenin lived long enough to make a decisive pronouncement on cybernetics, this did not prevent Kolman or the critics of cybernetics from using quotation-mongering. "Materialist," the author of the vitriolic 1953 attack on cybernetics "Whom Does Cybernetics Serve," literally argued that Marx had "foreseen" cybernetics and prepared arguments against it in advance:

> The great founder of Marxism brilliantly foresaw the possibility of such a degradation in the thought of the learned servants of the ruling classes. . . . "The result of all our discoveries and all our progress is obviously the endowment of material forces with spiritual life and the debasement of human life to the plane of material force." (K. Marx, *Works,* XI, Part I, pp. 5–6)[64]

Kolman proved no less knowledgeable of Marx's legacy, and he managed to find another brilliant forecast by the great founder, this time in support of the cybernetic cause. Citing a different passage from Marx and explaining what Marx really "wishes to say," Kolman refuted the common accusation of cybernetics of philosophical mechanicism as follows:

> After all our brain and our whole nervous system are just as material as our hands and the machines created by our hands; and our very thoughts and abstract ideas are also offsprings of matter. . . . In this evaluation we can refer to the authority of Marx. . . . Here Marx, when he speaks of devices such as the telegraph, emphasizes that they are not simply an extension of our hands but organs of the human brain. Evidently Marx wishes to say that within certain limits the human brain can be extended just as our hands can be.[65]

Several years later, Kolman reinterpreted this passage as Marx's direct approval of cybernetic machinery: "Until recently, machines were mostly just 'extensions' of our hands, not 'organs of our brains,' as Marx as early as a century ago called (then future, but now contemporary) cybernetic machines."[66] According to Kolman, Marx had not only anticipated the advent of cybernetics; he had even prepared a proper term for computers: "organs of the human brain."

Both sides in this "battle of quotations" used newspeak to take advantage of one fundamental ambiguity in Soviet philosophical discourse: the material and spiritual realms were considered both separate (they belonged to different forms of movement of matter) and unified (consciousness was defined as a product of highly organized matter). The (il)legitimacy of the analogy between mind and machine could thus be rhetorically argued both ways, depending on what was emphasized: separation or unity.

Label-sticking was also used in equal measure by Kolman and by the critics of cybernetics. The critics accused cyberneticians of idealism; in response, Kolman attached the same label to the critics. If the validity of the analogy between mind and machine were denied, he contended, one would have to appeal to a miracle in order to explain the ability of machines to compute, translate, play chess, and so on. He warned that this would mean accepting the "vital force" theory and succumbing to "all the mysticism of vitalism."[67]

Kolman effectively launched an anti-anti-cybernetics campaign with the same tools of philosophical criticism of science that he himself, along with other militant Marxist philosophers, had employed in the ideological discourse on science in the 1930s and the 1940s. Once he had corrected scientists' "deviations"; now he corrected the "deviations" of philosophers. Marginalized in the philosophy community after his imprisonment, Kolman turned into an uncompromising critic of the Soviet philosophical establishment. He strove to update dialectical materialism to incorporate recent scientific and technological developments, but he did not question the role of Soviet philosophy in scientific discussions.

After giving his pro-cybernetics lecture at the Academy of Social Sciences, Kolman marched right into the editorial office of *Voprosy filosofii* (which had published the notorious ideological attack on cybernetics "Whom Does Cybernetics Serve?") and offered the text of the lecture for publication. The editorial board initially rejected it but soon reversed its decision.[68] The reason for the reversal was that it had received another pro-cybernetics article, "The Main Features of Cybernetics," signed not by a marginalized philosopher but by three defense scientists, including the chief mathematician of the Soviet atomic project. In August of 1955 both articles appeared in one issue of the journal, presenting two divergent images of cybernetics: while

Kolman's essay attempted to reconcile cybernetics with dialectical materialism, the scientists' article intended to make philosophical discussions of cybernetics irrelevant.

The Military Defense of Cybernetics

The three co-authors of "The Main Features of Cybernetics"—the mathematicians Sergei Sobolev and Aleksei Liapunov and the computer specialist Anatolii Kitov—had one thing in common: all of them actively participated in military applications of the first Soviet computers. In this article, they attempted to synthesize Norbert Wiener's eclectic assembly of man-computer analogies into a single coherent theory, and to fashion a Soviet version of cybernetics as a comprehensive guide to the use of computer models in military affairs, industrial production, biology, and neurophysiology.

Aleksei Andreevich Liapunov (1911–1973)—the reputed "father of Soviet cybernetics"[69]—was undoubtedly the most ardent and persistent

Figure 4.3
Aleksei Liapunov. Courtesy of Natal'ia Liapunova.

advocate of cybernetics in the Soviet Union.[70] Born into a noble family in Moscow and schooled at home, he had studied at Moscow University and worked at the Mathematical Institute of the Soviet Academy of Sciences. Soon after the Nazi invasion of the Soviet Union, he had voluntarily joined that army, serving as an artillery officer until the end of the war. While at the front, he had joined the Bolshevik Party. In 1945–1951 he had taught mathematics at the Military Artillery Engineering Academy. In 1952 he had joined the Department of Computational Mathematics of Moscow University, where he had taught the first university course in computer programming in the Soviet Union. Liapunov was one of the very first users of the MESM, the first Soviet electronic digital computer. In 1953 he had joined the Applied Mathematics Division of the Soviet Academy of Sciences in Moscow, an elite institution engaged in mathematical research for the construction of nuclear weapons and ballistic missiles, and he had become the head of its department of computer programming.

Broadly educated, Liapunov kept abreast with most recent scientific developments in the West; he had many friends among biologists, and he was particularly interested in the intersection between biology, mathematics, and computing. Wiener's *Cybernetics* captured his imagination at once. Liapunov was regularly invited to various academic institutions—the Energy Institute, the Mathematical Institute, the Institute of Precise Mechanics and Computer Technology, the Biology Department of Moscow University, and many others—to give public lectures on the prospects of computing, and he often used such occasions to speak on cybernetics. Liapunov included under the rubric of cybernetics not only the set of ideas expounded in Wiener's 1948 book but also the whole range of computer applications developed in the West since 1948 for the automation of production, military control systems, economics, and other areas.

In the autumn of 1954 Liapunov organized a "seminar on machine mathematics" at Moscow University. He did not limit seminar topics to purely mathematical problems, however. Liapunov himself delivered a paper on "non-arithmetic use of computers" and gradually incorporated the entire range of cybernetic issues into the seminar's agenda. Liapunov's seminar met regularly for several years and served as a nexus of public exchange of cybernetic ideas. It attracted hundreds of participants, including leading Soviet mathematicians, computer programmers, biologists, linguists, physiologists, and economists. While cybernetics was still referred to in the press as a "reactionary pseudoscience," the participants of Liapunov's seminar openly discussed most recent Western cybernetic works on computer models of conditional reflexes and a mechanical mouse that could run mazes.[71]

In May of 1955 the computer designer Isaak Bruk published "On Control Machines" in *Priroda*.[72] Trying perhaps to avoid ideological complications, Bruk did not use the language of cybernetics. Liapunov, who had reviewed this article for the journal, used the occasion to emphasize the need to propagandize cybernetics:

> The issue discussed [in Bruk's paper] belongs to a new trend in contemporary science called *cybernetics*. . . . In our [Soviet] literature, this trend is grossly underrepresented. Moreover, it is often distorted. Bruk's article is one of the first articles in Russian where problems of cybernetics are presented correctly. It is desirable that after the publication of the reviewed article the journal *Priroda* publish a number of survey articles on cybernetics. I believe that one should not eschew the term *cybernetics* in those articles.[73]

Figure 4.4
Sergei Sobolev. From Bitsadze, ed., *Sergei L'vovich Sobolev (K 60-letiiu so dnia rozhdeniia)*.

As a professor in the Department of Computational Mathematics at Moscow University, Liapunov had close contact with Sergei Sobolev, the department's chairman and the chief mathematician of the Soviet atomic project. Sergei L'vovich Sobolev (1908–1989) was among the most influential Soviet mathematicians of his time.[74] Born into the family of a prominent lawyer in St. Petersburg, he graduated from Leningrad University in 1929, and the Steklov Mathematical Institute in 1932. In 1936–37 he chaired the Department of Higher Mathematics at the Military Technical Academy. Sobolev produced impressive theoretical results with important practical applications for national defense, and his career skyrocketed: in 1933, at the age of 25, he became the youngest ever corresponding member of the Soviet Academy of Sciences, and in 1939 he was elected the youngest full member of the Academy. Also in 1939 he was appointed Deputy Director and later Director of the Mathematical Institute. In parallel with the successful scientific career, Sobolev made smart political moves: in 1937 he was elected member of the Supreme Soviet of the Russian Federation, and in 1940 he joined the Bolshevik Party. In 1943 he was trusted with a top-priority government assignment: he became Deputy Director of the Institute of Atomic Energy and began supervising the mathematical part of the Soviet nuclear weapons program. The subsequent successes in the construction of the first Soviet atomic and hydrogen bombs brought him the Stalin Prize and the prestigious title of Hero of Socialist Labor. While working at the Institute of Atomic Energy, Sobolev later recalled, he "developed a taste for computational mathematics and came to know its exceptional possibilities."[75] He actively employed the first Soviet digital computers to solve complex mathematical problems associated with the design of nuclear weapons.

The third co-author of "The Main Features of Cybernetics," Anatolii Ivanovich Kitov, was a former student of Liapunov's at the Military Artillery Engineering Academy. Upon graduation, he had been assigned to Special Design Bureau 245 of the Ministry of Machine and Instrument Construction to study the prospects for military applications of computers.[76] In the autumn of 1953, at the request of Deputy Minister of Defense Aksel' Berg, Kitov delivered a report on digital computers at a session of the Scientific-Technical Council on Radioelectronics, headed by Berg.[77] Soon Kitov was appointed deputy head of the newly established Computation Center 1 of the Ministry of Defense. He authored one of the first Soviet books on digital computing.[78] While Liapunov propagandized

Figure 4.5
Anatolii Kitov. From Malinovskii, *Istoriia vychislitel'noi tekhniki v litsakh*.

cybernetics in academic institutions, Kitov was giving talks and circulating papers on cybernetics in military circles.

In their 1955 article, Liapunov, Sobolev, and Kitov made a deliberate attempt to "upgrade" cybernetics to the status of fundamental science. What Wiener called "the feedback mechanism" they called "the theory of feedback"; "basic principles of digital computing" became "the theory of automatic high-speed electronic calculating machines"; "cybernetic models of human thinking" became the "theory of self-organizing logical processes."[79] Soviet cybernetics transcended the domain of engineering and fashioned itself as a science—a systematic study of the laws of nature. The "nature" that cybernetics studied, however, was of a special kind: it was an "objective" world constituted by information exchanges and control processes. "The laws of existence and transformation of information are objective and accessible for study," wrote Liapunov's close associate Igor' Poletaev. "The determination of these laws, their precise description, and the use of information-processing algorithms, especially control algorithms, together constitute the content of cybernetics."[80]

Liapunov, Sobolev, and Kitov underscored the fundamental theoretical character of cybernetics by using the word *theory* six times in their definition of the new discipline. Cybernetics, they asserted, consisted of three main branches:

(1) information theory; particularly, the statistical theory of processing and transmitting messages;
(2) the theory of automatic high-speed electronic calculating machines as a theory of self-organizing logical processes similar to the processes of human thought;
(3) the theory of automatic control systems; particularly, the theory of feedback, including the study of the nervous system, sensory and other organs of living beings from the functional point of view.[81]

Although Liapunov, Sobolev, and Kitov purported only to explicate the existing cybernetic ideas, their version of cybernetics differed from Wiener's eclectic collage in several important respects. First, they chose the computer rather than the servomechanism as an archetypal cybernetic machine. They therefore broadened the subject of cybernetics to encompass not only feedback models but also computer algorithms. Second, they attached a very broad meaning to the notion of information, defining it as "all sorts of external data, which can be received and transmitted by a system, as well as the data that can be produced within the system."[82] Liapunov et al. called "information" any environmental influence on living organisms, any knowledge acquired by man in the process of learning, any signals received by a control device via feedback, and any data processed by computer. In their view, cybernetics was based on a "doctrine of information," which included the traditional information theory ("the theory of communication") as one of its components:

In the doctrine of information, cybernetics combines common elements from diverse fields of science: the theory of communication, the theory of filters and anticipation, the theory of tracking systems, the theory of automatic regulation with feedback, the theory of electronic calculating machines, physiology, and so on. Cybernetics treats various subjects of these sciences from a single point of view—as systems that are processing and transmitting information.[83]

Liapunov, Sobolev, and Kitov viewed the computer not only in its traditional cybernetic role—as a structural analog of the nervous system (with electronic switches compared to neurons)—but also as a functional analog of any control system (with logical operations in a computer program fulfilling the control function). Any computer application was thus "cybernetic" in the sense that it was an implementation of a certain control process. Cybernetics was a theoretical science that could be "applied"—by providing guidance for computer applications—in various spheres of science and technology. Liapunov et al. realized that identifying cybernetics with a general theory of computer applications would help extend the legitimacy of computer developments, which were extremely important in the eyes of Party and government authorities, to the legitimacy of cybernetics itself.

Skillfully using the "overtake and surpass" argument, Liapunov, Sobolev, and Kitov cited Western accomplishments in aircraft gun control and industrial automation and pointed to the "great economic and military significance" of cybernetics.[84] Wiener's original version of cybernetics came into existence when computers were a rarity and their prospective applications were still uncertain. By the mid 1950s, however, computers were already being used to control complex production processes and weapons systems. Soviet cybernetics stood on the shoulders of advanced computing and became more computer-centered and more ambitious in its general claims than its American counterpart.

Besides making the pragmatic argument about the great practical value of cybernetics, Liapunov, Sobolev, and Kitov also faced the question of how to ideologically legitimize cybernetics, previously labeled "a reactionary pseudo-science." To remove any trace of ideological suspicion toward this new discipline, they had to construct a new ideological image of cybernetics and to redefine its relationship with dialectical materialism, the official Soviet philosophy of science.

Cyberspeak Challenges Newspeak

The first Soviet cyberneticians did not even try to reconcile cybernetics with dialectical materialism. Instead of drawing a line between the "objective content" of cybernetics and its "philosophical interpretation," they insisted that questions of philosophy and ideology were completely irrelevant here. Rather that try to conform to the rules of the official philosophical discourse, they attacked its foundations.

Liapunov, Sobolev, and Kitov chose to publish their original defense of cybernetics not in a journal of mathematics or engineering but in the leading philosophical journal, *Voprosy filosofii*. Their pro-cybernetics argument was carefully constructed to avoid any direct confrontation with the philosophical postulates of dialectical materialism—such a confrontation would be still politically dangerous and unwise—but to challenge one of the key principles on which the official philosophical discourse was based: the principle that philosophical dogmas came first and scientific knowledge second, and the latter had to conform to the former. They strove to validate cybernetics in its own right and to make philosophical discussion irrelevant. Moreover, they aspired to make cybernetics a showcase for exposing the inappropriate interference of "philosophers" with science.

Liapunov, Sobolev, and Kitov vigorously attacked "our philosophers" for "misinterpreting cybernetics, suppressing cybernetic works, and ignoring the practical achievements in this field." Cunningly turning the accusation of "kowtowing before the West" upside down, they argued that the critics of cybernetics themselves fell prey to Western propaganda: "Some of our philosophers made a serious mistake: without understanding the issue, they began denying the validity of a new scientific trend largely because of the sensational noise made about it abroad." Mocking the Stalinist era's paranoid suspicion of anything foreign, characteristic of the Soviet critics of cybernetics, they suggested that the ideological critique of cybernetics itself had been in fact inspired from abroad:

> One cannot exclude the possibility that the hardened reactionary and idealistic interpretation of cybernetics in the popular reactionary literature was specially organized to disorient Soviet scientists and engineers in order to slow down the development of this new important scientific trend in our country.[85]

The opponents of cybernetics were thus portrayed as simpletons duped by bourgeois propaganda. As David Holloway has observed, "the hostile image of capitalist society which had played an important part in the early attacks on cybernetics, was now turned to its defense."[86]

Liapunov, Sobolev, and Kitov not only accused "philosophers" of specific ideological blunders; they also argued that philosophical criticism of cybernetics in general was irrelevant, for philosophers were incompetent to judge scientific issues. They called for "casting aside the talk about cybernetics as a 'pseudoscience'—a talk which covers elementary ignorance in the questions of science."[87] To deny the validity of cybernetic claims on philosophical grounds, they warned, would be ideologically dangerous. During a discussion of their manuscript in the *Voprosy filosofii* editorial office in May of 1955, Liapunov argued passionately:

If we refuse to consider the possibility that a computer can do scientific research, and tomorrow something [of this sort] happens, they [in the West] will say: "Your ideology and your forecasts are worthless." . . . It is inaccurate to say that creativity is unreachable for computers. . . . Imagine that the capabilities of computers develop further and certain things become reachable. Then they will say that we based our forecasts and research guidelines on ideological considerations, and those forecasts have failed.[88]

Liapunov, Sobolev, and Kitov argued that "the limits of applicability of electronic and mechanical models and schemes for the representation of thinking" could be determined not by philosophical analysis, but only by electronic modeling and physiological experiments.[89] In other words, cyberneticians were to solve their problems themselves with the help of cybernetic methods; philosophy had no role to play here.

Liapunov, Sobolev, and Kitov plainly refused to use the conventional terminology of newspeak and insisted on the validity of the language of cybernetics. The Deputy Editor-in-Chief of *Voprosy filosofii*, Mark Rozental', objected to the use of the word *memory* with respect to computers, arguing that memory was a mental attribute.[90] Kitov replied that memory was nothing more than "the ability to preserve information" and contended that "one should not be afraid of calling this thing *memory* both here and there [in men and machines]." "Why can't we say *memory* but have to say *storage device*?" he asked.[91] "The matter is to preserve a difference between man and machine," Rozental' explained.[92] "The real difference is that man is a social being; he is formed under the influence of his [social] environment. There is no need to see a difference where it is not even tangible," Kitov retorted.[93] In the end, the cyberneticians' position prevailed, and the final version of the article contained this sentence: "Memory is an important function of both the nervous system and computing machines."[94]

Instead of developing a philosophical defense of cybernetics and arguing its compatibility with dialectical materialism, as Kolman did, the first Soviet cyberneticians directly challenged the very principle that science had to comply with philosophy. In October of 1958, speaking on cybernetics at the All-Union Conference on Philosophical Problems of Natural Science, Sobolev brushed aside the philosophical critique of cybernetics as utterly irrelevant:

We [Sobolev and Liapunov] admit that we do not even understand some of these [philosophical] questions in relation to cybernetics. Sometimes we are forced to hear from philosophers the request to "explain materialistically the philosophical meaning of electronic computing machines." We must confess that we do not quite understand how one can explain the philosophical meaning of electronic computing machines.[95]

Sobolev bluntly refused to speak in philosophical terms (at a philosophy conference!) and proclaimed: "One cannot divide physics into materialistic physics and idealistic physics. One cannot say that this atomic bomb is materialistic, and that one idealistic, this particle accelerator is idealistic, and that one materialistic. There is no such thing."[96] The huge audience (nearly 600, mostly philosophers) was shocked, and his opponents complained to the Party Central Committee. In an internal report, a Party functionary quoted Sobolev's remarks as follows:

> Cybernetics is neither mechanistic, nor idealistic. It is first and foremost a science of facts. There can be no idealistic or materialistic facts; a fact is always a fact. Cybernetics, a science of control systems, studies facts that exists in reality, and it would be outlandish to call cybernetics an "idealistic science."[97]

Sobolev did not use any philosophical arguments to refute the charge of idealism; instead, he claimed that philosophical terminology simply was not applicable to cybernetics.

Sobolev and Liapunov contended that cybernetics would solve its problems by itself, without recourse to philosophy:

> The question about the differences and surface similarities between the work of the brain and the work of computing machines—the question that recently has aroused somewhat unhealthy interest—belongs, in our opinion, not so much to philosophy but to cybernetics proper, and it must be solved by the accumulation of experience in this science.[98]

The cyberneticians' attack on newspeak openly questioned the dominant status of philosophers in the academic community. "How can cybernetics be judged by people who never wrote a single computer program?" Sobolev asked rhetorically. "I think it should be reflected in the resolution of our meeting that only those who have accomplished something real in science may work in the field of philosophy of science."[99] The conference indeed adopted a resolution that called on philosophers of science to study the "corresponding areas of natural science," as well as on scientists to study dialectical materialism.[100]

Sobolev's opponents complained to Party authorities that he had "diminished the significance of materialistic generalization and interpretation of cybernetic research," but their complaints were in vain.[101] Sobolev's mention of the atomic bomb was far from casual; his leading position in the Soviet nuclear weapons program placed him beyond the reach of philosophers' criticism.

Whereas for Kolman legitimizing cybernetics was largely a matter of clearing it of previous charges, the cyberneticians attacked the very basis of those charges: the authority of philosophers to judge scientific controversies. For them the legitimization of cybernetics was not a defensive action; it was an offense against the dominant position of ideological discourse in Soviet science, most prominently in biology.

Cybernetics and Genetics: A Common Cause

The "father of Soviet cybernetics," Aleksei Liapunov, had developed a long-term friendship with a number of leading Soviet geneticists since the early 1940s, when he was involved in a controversy between Kolmogorov and Lysenko over the validity of statistical analysis in the interpretation of genetic experiments.[102] In the late 1940s, Liapunov organized a *kruzhok* (a "circle," a home study group) for his two school-age daughters Elena and Natal'ia and their friends interested in biology, and taught them the fundamentals of genetics.[103] In 1954, when his daughters entered the Biology Department of Moscow University, they were among the few students there familiar with classical genetics. The meetings of Liapunov's kruzhok became more crowded, for he offered informal courses on genetics and the theory of probabilities and statistics, which were not taught to biology students at the university. Risking his position as a Party member and a researcher at a closed institution working on classified projects, Liapunov often invited persecuted geneticists to give guest lectures and transmit their "forbidden knowledge" to this select group. Geneticists, who were virtually isolated from the scientific community, seized this opportunity to communicate with the younger generation. Such prominent biologists as Dubinin, Romashov, Sakharov, Timoféeff-Ressovsky, Zavadovskii, and Zhebrak spoke at the meetings of Liapunov's kruzhok.

Liapunov's kruzhok cultivated the spirit of free thought. The ideological rituals and taboos of official discourse were often violated and ridiculed. In the summer of 1955 Liapunov visited his daughters in Chashnikovo, where they were receiving practical training. At a campfire, he joined a student chorus singing anti-Lysenkoist satiric songs (*chastushki*) that poked fun at Lysenko's ideological critique of "Mendelism" and "formalism" in genetics. The performance concluded with a mocking "hymn of Morganists" sung to the tune of the popular song "Katiusha":

Hey, my song, Mendelist's song,
You fly to Lysenko's farms
And bring to this marvelous giant of thought
Our formal regards.
Let him learn how genes work,
What chromosomes' design is,
Let him save potato stock,
And Mendel will save science.[104]

Liapunov's anti-Lysenkoist activity included, however, actions much more serious than *chastushki*. In October of 1955 the Presidium of the Party Central Committee received a letter from 94 Soviet scientists (including 70 biologists) harshly criticizing Lysenko for damage done to Soviet biology.[105] Such influential physicists as Kapitsa, Landau, Sakharov, Tamm, Artsimovich, and Zel'dovich signed the letter, which read as follows:

> The grave consequences of T. D. Lysenko's monopoly in science have not been eliminated, and as the result, Soviet biology and agricultural science in general are falling far behind world science. . . . Material losses that our country suffered as the result of Lysenko's activity are so great that they cannot be adequately measured. . . . For many years, Lysenko's false theoretical principles have been portrayed as a new step in the development of a dialectical materialist understanding of biological phenomena. In reality, Lysenko's views make up an amazing mixture of mechanicism, idealism, and plain ignorance.[106]

In February of 1956 Party authorities received an addendum signed by 203 scientists.[107] Together the 1955 and 1956 appeals became known as a "letter of 300 [signers]." Liapunov signed the addendum and took an active part in soliciting signatures from influential Soviet scientists; in particular, he managed to obtain Sobolev's support. The signatures under the addendum were divided into two categories: biologists and non-biologists. Using his broad contacts among mathematicians and biologists, Liapunov attracted scores of supporters from both communities. In the heat of the moment, Liapunov did not notice that he had signed the letter twice—once with the biologists, once with the non-biologists.[108] One signature, however, was already enough to get the signer into trouble.

The Science Department of the Party Central Committee saw the "letter of 300" as a sign of outrageous insubordination. The head of the Science Department, Vladimir Kirillin, reported as follows to the Central Committee:

The presence of a collective letter from scientists on the issues of biology indicates that the presidiums of the Academy of Sciences and the Academy of Medical Sciences, the Ministry of Higher Education, and the Ministry of Agriculture exercise extremely weak control over criticism and self-criticism in biological institutions and journals. An exchange of opinion among scientists on important and controversial issues of biology is not properly organized and takes a spontaneous character.[109]

Lysenko's supporters took their countermeasures and had their criticism "properly organized." In December of 1955 the anti-Lysenko letter was discussed at a Party meeting at the Biology Department of Moscow University, a stronghold of the Lysenkoites. Professor Dobrovol'skii, head of the Party bureau, unequivocally denounced the letter:

Many probably already know that some faculty members put their signatures under a collective letter to the Party Central Committee (the letter seems to have originated from the Academy of Sciences), in which the activity of Academician Lysenko was condemned. No one is prohibited to appeal to the Central Committee on any issue. [Nevertheless,] participation in such collective letters that bypass public and Party organizations, is absolutely unacceptable. We must harshly condemn such methods, which have nothing to do with open scientific discussions![110]

The meeting's resolution censured the "method of clandestine collection of signatures among the faculty . . . as a method of scientific discussion which is inappropriate for Soviet scientists."[111]

At the same meeting, Lysenkoites denounced the circles of "young Morganists" who were spreading the bacilli of "formal genetics." Professor Chumak specifically named Liapunov's kruzhok: "Students gather at Professor Liapunov's home. . . . They chatter about Lysenko, about his behavior, and so on."[112] The Lysenkoites were particularly outraged by the anti-Lysenko songs: "During practical training, [students] sang *chastushki* around a campfire; these *chastushki* discredited Lysenko and the Michurinist approach [in biology]."[113]

In February of 1956, just a few days after the addendum with Liapunov's signature reached the Central Committee, the Party bureau of the Biology Department gathered to discuss their response. At the same meeting, the issue of Liapunov's kruzhok was also brought up. The Lysenkoites put two and two together, and decided to focus their criticism on the activity of Liapunov and his daughters.[114] Party activists attempted to provoke the expulsion of Liapunov's daughters from the Komsomol (the Young Communist League), which most certainly would have led to their expulsion from the university, but they failed. Elena and Natal'ia got off with just a severe formal reprimand for their "superficial approach to science, which found expression in the uncritical attitude toward ideas expressed at home circle meetings, and for the loss of Komsomol vigilance."[115]

Liapunov's propagation of cybernetic ideas was closely connected with his defense of genetics. Intellectually, cybernetics provided a framework for the use of mathematical methods in biology. Politically, cybernetics and genetics went together as two "reactionary and idealistic" sciences subjected to ideological criticism under Stalin. The Lysenkoites quickly recognized cybernetics as a threat. In late February of 1956, at a meeting of the Party bureau of the Biology Department, Professor Studitskii alerted his comrades to the enemy's attempts to "bring mathematics into Mendel's rules [of genetics], to involve cybernetics and other research tools employed abroad"; he warned that cybernetics was an "alien ideology" that caused "unhealthy incidents."[116] Professor Dvoriankin followed suit: "Where did [students] get the idea that cybernetics provided a new interpretation of the laws of heredity? . . . They got it from those biologists who did not agree with the resolutions of the August session [the pro-Lysenko resolutions of the July-August 1948 session of the Academy of Agricultural Sciences]."[117] Another speaker, Serenkov, pointed his finger directly at Liapunov:

> I don't even want to talk about Liapunov's circle, so utterly disgusting it is. The whole direction of this circle shows that it is totally alien to our Soviet reality. This [circle] is aimed at educating our young people in a certain spirit, which is not the spirit of Marxism-Leninism. . . . If we want to educate our young people correctly, then we must keep them away from the education they receive in Liapunov's circle.[118]

After the publication of Liapunov's article on cybernetics in *Voprosy filosofii*, the Lysenkoites did not dare to attack cybernetics per se; however, they questioned its applicability to biology.

At a meeting of the Moscow University Party Committee in late February of 1956, Professor Dvoriankin pointed to the probabilistic apparatus of cybernetics as a root of serious errors committed by Soviet geneticists and cyberneticians: "Through the interest in cybernetics (which should be developed further and interpreted correctly), the interest in the wrong theory of randomness emerges. They put forward the theory of random mutations. They claim that the law of inheritance of acquired traits is not proved experimentally. They claim that Morganist genetics has achievements."[119] Another speaker, Isaev, argued that a cybernetic approach to biology was incompatible with Marxism: "It is typical of Morganism to think of nature as a chaotic assembly of random events. . . . Do we really need, comrades, to prove how groundless are all these speculations of cyberneticians in the spirit of Morganism? Science is the enemy of chance. That's what Marxism teaches us."[120]

While the Lysenkoites questioned the validity of cybernetic methods in biology on ideological grounds, Liapunov, who was also present at the meeting, insisted that this was a "scientific issue." He tried to turn the discussion toward mathematical questions and away from speculations about Marxism:

> I will start with scientific issues. One cannot detach ideological issues from scientific ones, and many of the ideological issues discussed here have scientific origins. . . . To claim a chaotic assembly of random events is one thing; to use methods of the theory of probability is quite another. . . . I am absolutely convinced that the use of statistical methods in biology is not a sin; on the contrary, the use of such methods is a powerful tool for the improvement of our biological knowledge.[121]

"But how about the Marxist method?" asked someone. "One does not exclude the other," replied Liapunov. "Mathematical methods are part and parcel of the Marxist materialist methodology." Implicitly rejecting the guidance of Marxist philosophy, Liapunov insisted that science was already in harmony with dialectical materialism and needed no philosophical oversight: "Dialectical materialism and Marxist philosophy do not throw away or exclude technical methods of study adopted in natural science, and vice versa."[122] Professor Kuperman, an active Lysenkoite, disagreed, reiterating the belief in the dominant role of Marxist ideology in science: "We will use the method of dialectical materialism in the first turn; and only in the second turn, if necessary, will we use mathematics."[123]

Party activists at Moscow University harshly condemned Liapunov for his "grave mistake" of organizing a genetics home study group without the authorities' permission, but they were unable to prosecute him. He taught at Moscow University, but officially he belonged to the local Party organization at the Applied Mathematics Division, his home institution; therefore, his affair was outside the authority of Moscow University's communists. The director of the Applied Mathematics Division, Academician Mstislav Keldysh, who had himself signed the "letter of 300" against Lysenko, stated "We have no evidence to suggest that comrade Liapunov abandoned the materialist position in biology," and the division's communists let Liapunov go.[124]

Many mathematicians and physicists in the defense sector had little respect for the Lysenkoites' ideological arguments, and generally viewed philosophical discussions as an intrusion into the intellectual territory of science. The rise of cybernetics provided a vehicle for undermining the dominant ideological role of philosophers in Soviet science.

Cybernetics Challenges Soviet Philosophy

During the "thaw," Soviet scientists often cited Soviet philosophers' participation in the anti-cybernetics campaign of the early 1950s as direct evidence of philosophers' ignorance and inappropriate interference in scientific questions. "The philosopher" was blamed for all calamities in Soviet genetics, physics, physiology, or cybernetics. By attacking "philosophy," scientist critics aimed at a larger target: the entire Stalinist ideological discourse on science, which was often couched in philosophical terminology. Fighting against "the philosopher," scientists in effect rebelled against the Party ideologue, the overcautious editor, and the Party-minded colleague.

Physicists argued that philosophical criticism of cybernetics was as nonsensical as similar escapades against relativity theory and quantum mechanics. Petr Kapitsa quoted the definition of cybernetics as a "reactionary pseudo-science" from the 1954 edition of the *Short Philosophical Dictionary* to accuse philosophers of obscurantism:

> Had our scientists back then accepted that definition as a guide to further development of this particular science, we may safely say that our conquest of space, of which we are so justly proud and for which the whole world respects us, could never have been accomplished, since it is completely impossible to guide spacecraft without cybernetic machines.[125]

The leading specialist in the theory of algorithms, Andrei Markov Jr. (the son of Andrei Markov Sr., whose work was discussed in chapter 3), publicly blamed philosophical attacks against cybernetics and other scientific theories on the Stalinist regime, to which Khrushchev in his 1956 "secret speech" had referred as "the cult of personality." In January of 1957, at a Party meeting at the Mathematical Institute of the Academy of Sciences, Markov expressed his disagreement with the view of his colleague Andrei Bitsadze that the recent rise of "adverse elements" in Soviet society had been inspired from abroad:

> I cannot agree with A.V. Bitsadze's conclusion that the roots of these abnormal phenomena that we encounter lie exclusively abroad. Such roots can be found in

our country as well. These roots are the errors committed in this country in connection with the cult of personality. There are philosophers here who gave a hostile reception to everything new in science. They shouted: "Cybernetics, the theory of [chemical] resonance, genetics, the theory of relativity—this is all idealism. And the 'discoveries' of Lepeshinskaia, Bosh'ian, and Lysenko—this is materialism." Students were taught not scientific biology but complete nonsense. . . . Such "philosophers" discredited philosophy in the eyes of the youth. . . . We fell far behind in machine mathematics; the United States is far ahead. This happened because there was the wrong policy: "All that is ours is good, all foreign is bad."[126]

Liapunov also expanded his criticism of philosophers' attacks on cybernetics to question philosophers' overall role in the academic community. In September of 1956, at a Party meeting at the Applied Mathematics Division, Liapunov called on his colleagues to rise up against philosophers' "interference in science":

Some philosophers [in this country] believe that they have a monopoly and the right to interfere in science, for example, in biology. Non-scientific views are thriving here on the biological soil, and these views come from Academician Lysenko. In the field of linguistics, there is an approach called structuralism, and it is labeled a pseudoscience. In recent months, these matters have been reevaluated. It is necessary to make philosophers' interference in science a subject of debate.[127]

Liapunov's dislike of official Soviet philosophy was so passionate that it took a poetic form. His family has preserved a manuscript of a poem he circulated among his close friends[128]:

From ancient times to present day
Philosophy—on guard,
Protecting scholars' thorny ways
From heresy and dark.
Philosopher will never let
A thinker deviate;
Philosopher will always stand
Self-confident and straight.
A scholar expounded boldly his faith:
"The earth is a miniature flake,
Lost among stars in the infinite space."
Philosopher burned him at stake.

Liapunov went on to recall the stories of Copernicus, Galileo, and Darwin, each time blaming the grisly figure of "the philosopher" for the persecution of scientists. Finally, he turned to the most recent events:

In our era, in search of the truth,
Science bypassed philosophy in its pursuits.
"To correct deviations!" philosophers rushed,

"Heresies must be found and crushed!"
Einstein is now exposed and expired
As a pitiful crook and congenital liar.
Quantum mechanics is put on display
As a top pseudoscience of our day;
And those who write equations
Are accused of undue deviations.
Their labs are closed to clear the space
And myths have taken the central place:
Abstract methods aren't applicable indeed
To the things that are invariably concrete.
Chemists probably dreamed up the evidence
Of the so-called "structural resonance."
A good lesson have learned physiologists:
"Don't invent inappropriate novelties!"
Only biologists got a free hand
To fantasize, speculate, and invent.
Life's now born straight out of dirt,
Genetics—thoroughly destroyed.
Morgan—crushed with a single stroke,
Mendel's head is on the block,
Virchow—broken on the wheel,
Weismann—next who will be killed.
Chromosomes turned into rubble;
Genes are now in big trouble.
By Lysenko's prayers, wheat
Turns more branching, nice and neat.
And philosophers' alliance
Reigns too freely over science.
Marxism safe under protection:
Watch obscurantists in action.[129]

By "Marxism," Liapunov—a loyal Party member and a believer in socialist ideas—appears to have meant not the actual teachings of Marx or Engels (who were known to have hailed the latest scientific developments, including Darwinism) but rather newspeak—the frivolous use of Marxist language in Soviet philosophical discourse. As David Holloway has keenly observed, only a few of those who participated in the anti-cybernetics campaign were professional philosophers; many critics of cybernetics were psychologists, biologists, or journalists. Holloway has argued that they were all labeled "philosophers" since the term "philosophy" stood here for a particular type of ideological discourse on science:

What [the "philosophers"] did have in common was their support for the politically sanctioned orthodoxies in biology and their appeals to the authority of those orthodoxies in their criticisms of cybernetics. Thus the term "philosopher" was used to describe not only professional philosophers and officials in the ideological apparatus, but also those who employed the Stalinist "techniques of persuasive argumentation" in natural scientific debate.[130]

As Loren Graham has convincingly demonstrated, leading Soviet scientists shared some of the basic principles of dialectical materialism, such as epistemological realism and non-reductionism, and some of them fruitfully applied these principles in their research.[131] When they attacked "philosophy," they targeted not philosophical theory but practice—the entire Stalinist political and ideological discourse on science. This discourse was often shrouded in philosophical terminology and expounded by professional philosophers, but it spread far beyond the traditional philosophical problematic. The stance against such "philosophy" was a political one; it was a stance against the Stalinist order of things.

The first Soviet cyberneticians used cybernetics to subvert and even displace official philosophy in public discourse. In particular, they managed to propagandize cybernetic ideas through the Party "network of political education," whose purpose was to instill proper ideology into the minds of Party and Komsomol members. The ideological uncertainty of the early post-Stalinist period left the question of exactly what was to be regarded as proper political education wide open. Soviet cyberneticians grasped this opportunity to fill the ideological vacuum with cybernetics.

Cyberneticians often used philosophical methodological seminars, which functioned as part of the Party educational network in academic institutions, as a vehicle for cybernetic discussions. For example, at the Mathematical Institute, Andrei Markov Jr. turned the institute-wide philosophical methodological seminar, where researchers were supposed to indulge in dialectical materialist analysis of their mathematical work, into a forum for discussing various mathematical innovations. In January of 1957 he presented a joint paper with Sobolev on the impact of computers on recent trends in mathematics. Party functionaries at the institute immediately sensed danger. One activist told his comrades to be careful with discussing at philosophical seminars "all kinds of new trends that emerged abroad, because, while criticizing them, we sometimes simultaneously propagate them."[132] Another critic proclaimed: "Our seminars must be closer to the classical principles of dialectical materialism."[133] The paper by Markov and Sobolev was particularly singled out for the "lack of philosophy." Dismissing such accusations, Markov sarcastically noted: "I think it would be wrong to have a great number of philosophical ideas in a single paper."[134] "If there are no quotations, this does not mean there is no philosophy," he remarked on another occasion, alluding to the standard newspeak technique of "quotation-mongering."[135]

Liapunov used the same venue—the local network of political education—to propagandize cybernetics. In the autumn of 1956 he offered to teach a seminar on cybernetics as a form of political education at his home institution, the Applied Mathematics Division. Local Party authorities did not object, as long as the seminar was officially devoted to "philosophy of cybernetics." Liapunov explained, however, that it was not possible to discuss the philosophical problems of cybernetics without first learning cybernetics itself, and he planned to devote three-fourths of the seminar time to the actual study of cybernetics.[136] Many researchers jumped on the opportunity to spend their obligatory hours of political education learning cybernetics, and Liapunov's seminar became very popular, especially among the younger generation. Listeners in the Division's network of political education could choose which seminar to attend, and the enrollment figures made their preferences explicit: foreign policy (68 listeners), domestic policy (21), political economy (9), the history of the Communist Party (2), Lenin's biography (8), contemporary philosophy (21), philosophy of cybernetics (71).[137] In the end, Liapunov spent no time at all on philosophical discussions; he gave two lectures on cybernetics himself and invited three guest speakers to lecture on genetics and neurophysiology.[138] This trick was noticed, however, and a representative from the district Party committee demanded that this seminar be excluded from the division's network of political education.[139] The Division's cyberneticians, however, justified the cybernetics seminar as an "experiment," and Liapunov continued teaching it until his departure from the Division several years later.

The word *cybernetics* began to appear in the popular press more and more often in a favorable context. Military experts also began to use this term in official reports, emphasizing the practical significance of this new field. Top science administrators began to argue that cybernetics was an important Western innovation that must not be missed. When the discussions of cybernetics gradually turned from debating its ideological value to finding ways to catch up with the Americans in this field, this meant that cybernetics was now legitimized.

The Legitimization of Cybernetics

In 1947, when Wiener was writing *Cybernetics*, the wide use of computers for scientific research and industrial automation was still a fantasy. By the mid 1950s, when open discussion of cybernetic ideas in the Soviet Union began, new computer applications were already becoming a reality. In Wiener's view, cybernetics was a collection of prophecies; in the Soviet context, cybernetics came to be seen as a scientific guide to a wide range of computer applications. In the eyes of Soviet officials, cybernetics became closely associated with computing, and the acceptance of computers effectively implied the legitimacy of cybernetics.

In March of 1955 a special government commission under the chairmanship of the Deputy Minister of Defense, Academician Aksel' Berg, prepared a secret report titled On the State of Radioelectronics in the USSR and Abroad and Measures Necessary for Its Further Development in the USSR. By that time, Berg had already heard about cybernetics from his subordinate Anatolii Kitov, one of the co-authors of the first pro-cybernetics article. Kitov's enthusiastic attitude toward cybernetics clearly shaped the assessment of this new field in Berg's influential report:

> A special place in the field of radioelectronics is occupied by so-called cybernetics (from the Greek word for "steersman"), which is a new scientific trend aimed at creating a general theory of control and communication in various systems. . . . As a result of irresponsible allegations by incompetent journalists, the word *cybernetics* became odious and cybernetic literature was banned, even for specialists, and this has undoubtedly damaged the development of information theory, electronic calculating machines, and systems of automatic control.[140]

In October of 1955 the Academy of Sciences, the State Committee on New Technology, and the Ministry of Higher Education submitted to the Party Central Committee an extensive secret report titled The Most Important Tasks in the Development of Science in the Sixth Five-Year Plan. The report stated that "more than 200 large universal electronic computing machines are currently in operation in the United States, while in our country, there are only three computers."[141] Of the sixteen most significant "revolutionary applications of new scientific discoveries" listed in the report, four related to the development of computing and control devices. While emphasizing the urgent need to catch up with the West in computing, the report also drew the attention of Party authorities to cybernetics and information theory:

In the upcoming five-year period, it is necessary to expand significantly works on probability theory and especially on its applications (including so-called information theory, which has received diverse applications in the West). It is imperative to achieve a radical improvement in the application of probability theory and mathematical statistics to various problems of biology, technology, and economics. The void existing here must be filled. . . . At present, a new field, "information theory," or so-called "cybernetics," which borders on mathematical logic and the theory of probabilities, is intensely developing in America, in both its theoretical and applied aspects. So far we have been very seriously lagging behind in this field. . . . The insufficient scale and poor organization of academic contacts with foreign science resulted in a very negative impact on the development of mathematics.[142]

Cognizant of the concluding remark, Party officials authorized the participation of a small Soviet delegation (five engineers) in the First International Congress on Cybernetics in Namur, Belgium, in June of 1956. About 600 participants from 21 countries attended the congress, where a very wide range of issues were discussed—from computer programming to machine translation to "thinking machines" to the problems of automation to the application of cybernetics in biology, physiology, medicine, and the social sciences. In a published report, one Soviet delegate wrote about cybernetics with great enthusiasm, arguing that analogies between humans and machines, especially between digital computers and the nervous system, would not only contribute to our understanding of the human organism but also help build better computers.[143] He assured his readers that the Soviet delegates' presentations had been received with "interest and approval."[144] In a confidential report for the Soviet Academy of Sciences, however, the members of the Soviet delegation sounded a different note, voicing serious concern:

Since in the Soviet Union the application of logical, computing, and control devices in various fields of science and technology is considerably lagging behind the developed countries, and the methods of cybernetics receive insufficient development, the delegation believes that it is imperative to expand drastically [Soviet] research in these directions in order to develop more advanced automatic machines and production processes.[145]

In October of 1956 the Academy of Sciences held a large session on industrial automation that featured a high-profile discussion of potential computer applications in various fields of science and technology. Opening the session, the president of the academy, Academician Aleksandr Nesmeianov, remarked: "We can see striking examples of huge leaps in the tempos and possibilities of scientific research owing to the introduction of one automatic machine—the high-speed electronic calculating machine."[146] Two leading computer designers, Lebedev and Bruk, delivered reports on the construction of computers and the bright prospects of their application for widespread automation in industry, transportation, economic planning, and military affairs. Other topics discussed included automation of computer programming, information theory, and automatic translation. Closing the session, Nesmeianov predicted that computer technology and information theory would produce a "great break" in industrial automation.[147]

The 1956 academy session became a turning point for Soviet cybernetics. Liapunov, who took most active part in organizing the session, coauthored two plenary reports: one on the mathematical aspects of computing, one on automatic translation. Contending that computers could now perform some intellectual functions, he argued that any intellectual process could in principle be mechanized as soon as its algorithm was found. He predicted that in the near future computers would control fully automatic factories, optimize transportation networks, and make economic decisions. The main condition for widespread automation, Liapunov said, was the "algorithmization" of control—that is, the reduction of a control process to a sequence of logical steps that could be implemented on a computer. Liapunov argued that the problem of describing, analyzing, and constructing control algorithms had central importance, and defined cybernetics as a field of study concerned precisely with this crucial problem of automation.[148] If computers lay at the heart of automation, cybernetics lay at the heart of every computer.

If during the anti-cybernetics campaign Soviet critics had rejected cybernetics wholesale and subjected every cybernetic claim to indiscriminate ideological criticism, now the situation was completely reversed. Many Soviet mathematicians and computer specialists embraced cybernetics enthusiastically and viewed any skepticism toward cybernetic claims as a manifestation of ideological obscurantism. For example, Anatolii Dorodnitsyn, director of the Academy of Sciences Computation Center, said:

> A while ago, super-orthodox philosophers tried to throw the baby with the bath water. The bath water was idealistic philosophy, which foreign philosophers

wrapped around computers and cybernetics; and the baby was actual computing machines and cybernetics. Now it is obvious to everyone that the wholesale repudiation of cybernetics was wrong, but the traces of anti-cybernetics "philosophical" articles still linger. One can often observe a skeptical attitude toward cybernetic tasks. Some people think that cybernetics borders on science fiction and mysticism. In fact, the immediate practical significance of cybernetics, especially with respect to control devices, is that cybernetics can play a big role not only in computation, but also in the modeling of logical thinking.[149]

Negative references to cybernetics in ideological literature quickly disappeared, and favorable references began to crop up. In the 1955 reprint edition of the *Short Philosophical Dictionary*, which in 1954 had defined cybernetics as a "reactionary pseudoscience," the critical entry on cybernetics was gone. One of co-editors of the *Dictionary* was Mark Rozental', Deputy Editor-in-Chief of *Voprosy filosofii*, which published two articles in support of cybernetics in 1955. Volume 39 of the *Great Soviet Encyclopedia*, prepared for publication in March of 1956, included, in accordance with alphabetical order, an article on the United States, and cybernetics supporters managed to slip in a mention of cybernetics as one of the sciences developed in that country. Volume 40, prepared for publication the next year, featured an article on the theory of communication; although cybernetics was not mentioned by name, the whole article expounded cybernetic ideas. A separate article on cybernetics finally appeared in 1958 in volume 51, which contained entries missing from the previous volumes. Andrei Kolmogorov, the mathematics editor of the *Encyclopedia*, wrote it himself. He unequivocally stated that cybernetics was not merely a collection of mathematical tools but a separate discipline with its own subject, thus dispelling the earlier doubts about the validity of cybernetics:

The much discussed issue of cybernetics' right to exist as an autonomous scientific discipline hinges upon the question how essential are the *common* features of all processes of communication, governance, and control, i.e., whether the common features of these processes in machines, living organisms, and their associations can be the subject of a substantive unified theory. This question must be answered in affirmative, even though only the first steps have been made in the direction of systematic construction of cybernetics.[150]

The same volume featured a separate article on information, also written by Kolmogorov. Cybernetics and information theory now had the "right to exist"; books and articles on these subjects could be published, new courses taught, and new institutions created. The year 1958 witnessed a flurry of books on cybernetics, including Russian translations of Wiener's

Cybernetics and *The Human Use of Human Beings*; the first volume of *Problemy kibernetiki* [*Problems of Cybernetics*], a new series edited by Liapunov; and Igor' Poletaev's *Signal*, the first original Russian book on cybernetics.

Support for the legitimization of cybernetics in the Soviet Union, ironically, came from two opposite sides. On the one hand, the banner of cybernetics was raised by the marginal philosopher Ernest Kolman, who challenged the dogmatists in the philosophical establishment but still believed in the mission of Soviet philosophy to oversee scientific developments. On the other hand, mathematicians and computer specialists, who resented the watchdog role of philosophy in Soviet science, picked up the language of cybernetics as a way to escape the official ideological discourse. Consequently, the two sides saw different ways out of the conflict between Soviet philosophy and cybernetics, which had developed during the anti-cybernetics campaign in the early 1950s. While the pro-cybernetic philosophers tried to reconcile dialectical materialism with cybernetics, the cyberneticians downplayed the whole issue of cybernetics' philosophical soundness and instead emphasized its experimental validity and practical utility.

Riding the crest of the computer wave, cybernetics attained full legitimacy in the Soviet Union. What exactly was legitimized, however, was not entirely clear to the authorities or to the cyberneticians themselves. How far could the analogy between the computer and the human brain go? What was the place of computer modeling in modern science and technology? What should be controlled by a computer and what should not? The situation of ideological uncertainty in society in general was mirrored in the uncertainty about the content, the boundaries, and the mandate of Soviet cybernetics. It was up to the Soviet cyberneticians themselves, in constant struggle with their opponents, to define their own discipline.

This Page Intentionally Left Blank

5

The "Cybernetization" of Soviet Science

[Cybernetics] aspires to study all control processes in living nature, in production, and in human society, that is, to embrace practically all human activity.
—Engineer Admiral Aksel' Berg, chairman of the Council on Cybernetics[1]

In the late 1950s, the popular image of an "objective," truth-telling computer became a vehicle for the emerging cybernetic discourse. Soviet mathematicians and computer specialists began to fashion a new discipline that would provide theoretical and practical guidance to computer modeling and supply techniques and technologies for transforming scientific knowledge into computer models and testing its validity. Soviet cyberneticians aspired to unify several diverse cybernetic theories elaborated in the West—control theory, information theory, computation theory, and others—in a single overarching conceptual framework that would serve as the foundation for a general scientific methodology applicable to a wide range of scientific and engineering disciplines.

The farther Soviet society departed from Stalinism, the more radical the cybernetic project became. Step by step, Soviet cyberneticians overturned earlier ideological criticisms of mathematical methods in various disciplines and put forward the goal of the "cybernetization" of the entire science enterprise—a much more ambitious agenda than was originally envisioned by Norbert Wiener in *Cybernetics*. A new concept of scientific objectivity associated with mathematics and computing lay at the core of this project. The Soviet cybernetics movement had a special mission: to bring objectivity to the entire family of the life sciences and the social sciences. Soviet cyberneticians believed that could accomplish this task by translating these sciences into cyberspeak. The precise language of cybernetics was to replace the vague and manipulative language of ideological discourse in fields that mathematics had not yet reached.

Having rejected the dominant role of philosophy in academic discourse, Soviet scientists put forward cybernetics as a substitute. They rejected a dogmatic Soviet version of dialectical materialism, but they accepted the premise that a universal philosophy of science, a general scientific methodology, or a meta-science was needed. Soviet cybernetics was constructed specifically to fulfill this function. In the United States, Wiener's original eclectic synthesis of diverse scientific and engineering concepts did not hold together; various threads of the cybernetic quilt—computing, control engineering, information theory, operations research, game theory—soon parted ways. Soviet cyberneticians, on the contrary, regarded cybernetics as the potential basis for a grand unification of human knowledge.

The cybernetics movement enveloped a broad range of disciplines, including mathematics, biology, physiology, linguistics, psychology, chemistry, economics, and legal studies. Cybernetics enthusiasts in different fields, however, often had very different ideas about the nature of a cybernetic approach. The disciplines brought under the cybernetic umbrella were unified at best by a Wittgensteinian "family resemblance." Defining the subject, the methods, and the theoretical principles of their discipline became an ongoing project of Soviet cyberneticians. In cybernetics, intellectual issues were closely intertwined with political debates and institutional disputes, and those disputes often focused on the meaning and the limitations of cyberspeak.

Cybernetics as a "Trading Zone"

Soviet cybernetics emerged in the Khrushchev era as a cross-disciplinary project that challenged some of the main dogmas of Stalinist academic discourse, particularly the rigid boundaries between scientific disciplines. During the Stalin era, such epistemological barriers served a political purpose: to invalidate the use of mathematical methods in the social sciences and the life sciences and to claim a special status for "natural historical laws" and "biological laws." Supporters of the infamous hack scientist Trofim Lysenko argued that biological laws could not be proved or disproved by mathematical or statistical means but only "on the basis of biology" (meaning the Lysenkoist doctrine). Lysenkoites portrayed mathematical processing of the results of genetic experiments as an impersonal, formal procedure that pulled the researcher away from the field, from nature, and from the truth. "We, biologists, do not take the slightest interest in mathematical calculations which confirm the useless statistical formulas of the Mendelists," proclaimed Lysenko. "We, biologists, . . . maintain that biological regularities do not resemble mathematical laws."[2] In the Stalinist system of science, each discipline was usually dominated by one officially endorsed school—e.g., the supporters of Lysenko in biology and the followers of Pavlov in physiology. The epistemological barriers between scientific disciplines helped the dominant school to protect its intellectual and institutional authority.

While liberal writers were searching for truth untainted by ideological canons, liberal scientists were looking for universal, objective scientific methods that would overcome the legacy of ideological dogmatism in various disciplines. The mathematician Andrei Markov Jr. summarized this contemporary sentiment as follows:

> One must not subdivide science into separate specialties with impenetrable fences, claiming that physicists should do [only] physics, mathematicians—mathematics, and biologists—biology. I think this trend is totally wrong and harmful. Science in essence is one, and all our classifications of the sciences are conventional. . . . Nature is one, and the sciences in essence comprise a single entity.[3]

Liberal scientists chose cybernetics as their primary weapon to break interdisciplinary barriers and legitimize the use of mathematical methods in the social sciences and the life sciences. They viewed cybernetics as an "exact science"[4] that, if applied to a given field of inquiry, would be capable of transforming that field into a rigorous research discipline. As one science journalist put it: "Cybernetics is probably the only possible instrument for reassembling the falling apart temple of science."[5]

Soviet authors called for a comprehensive "cybernetization" of modern science—that is, for representing the subject of every discipline in a unified, "formalized" way and moving toward a synthesis of the sciences.[6] In this sense, Soviet cybernetics was not a settled discipline but rather an ambitious project of systematic translation of scientific discourse into cyberspeak, which would make it possible for mathematical methods and computer models to penetrate the sciences without restraint.

Soviet cybernetics emerged as a "trading zone" where specialists from mathematics, computer engineering, biology, and physiology would meet and trade their theories, methods, concepts, and hypotheses. Gradually the nomenclature of the traded goods expanded to include theories and concepts from sociology, economics, linguistics, psychology, and many other fields. Cyberspeak served as a mediating language, a creole of sorts for this interdisciplinary trade. Cyberneticians themselves called it a "technical-mathematical-biological-psychological scientific language" to emphasize its interdisciplinary character.[7] By declaring cyberspeak a universal language of science, Soviet cyberneticians aimed at a radical transformation of the entire science enterprise along the path of mathematical formalization and computer modeling.

To emphasize the new mediating role of cybernetics, Soviet authors often presented their own versions of the "tree of knowledge." For example, in a chart drawn by Leonid Kraizmer, a leading Leningrad cybernetician, cybernetics lies at the center and ties all the natural sciences, the social sciences, and the humanities together. "Cybernetics," wrote Kraizmer, "embraces all sciences—not entirely, but only in the part related to control processes."[8] In full accord with the official view of dialectical materialism as a "science of all sciences," philosophy reigns over this kingdom of sciences. However, one cannot help but notice that cybernetics is the only field that is not subordinate to philosophy. Aleksei Liapunov, who led the cybernetics movement in Moscow and later in Akademgorodok in Siberia, envisioned a similar role for cybernetics—in the center of the tree of knowledge. Known for his aversion to the official philosophical discourse, Liapunov skipped philosophy altogether in his chart. He placed logic and mathematics at the top of his hierarchy of sciences. Cybernetics, along with physics and statistics, again takes the central position; its function is to provide methods for the natural sciences, engineering, and the humanities.

In Liapunov's view, cybernetics embraced all uses of computers for modeling and control. A crucial step in the "cybernetization" of various disciplines was the "algorithmization" of disciplinary knowledge, or its translation into cyberspeak:

> If until recently the algorithmic approach to the description of processes has been used in mathematics, mathematical logic, and some fields of technology, now the algorithmic approach to the description of phenomena must be sharply broadened and enter many new sciences. For example, the algorithmization of technological processes is required for production control; the algorithmization of linguistic processes is required for the implementation of machine translation. To transfer a wide range of human functions to a machine, the algorithmic modeling of the functions of thought and behavior is required, and here cybernetics borders upon biology and psychology.[9]

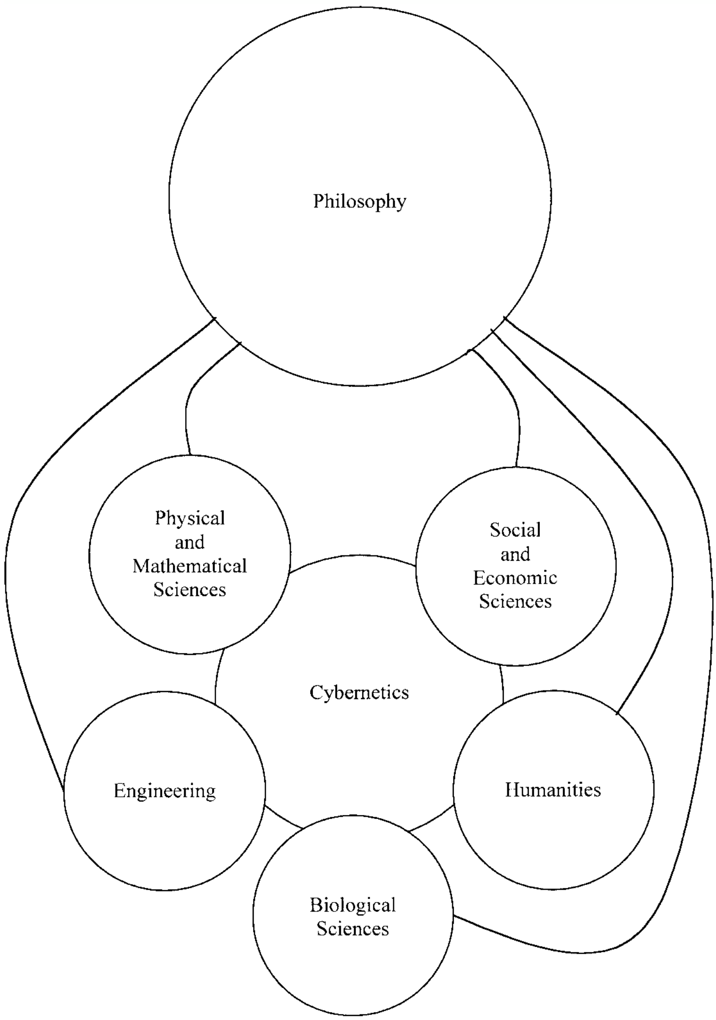

Figure 5.1
The interdisciplinary role of cybernetics. Adapted from Kraizmer, *Kibernetika*.

With Sergei Iablonskii, a colleague at the Applied Mathematics Division, Liapunov summarized the "cybernetization of science" project in a huge table, which included twelve methods of cybernetic analysis, such as determining information flows, deciphering the information code, and determining the functions and elements of a control system. Each method could be applied to each of the eight scientific and engineering disciplines listed

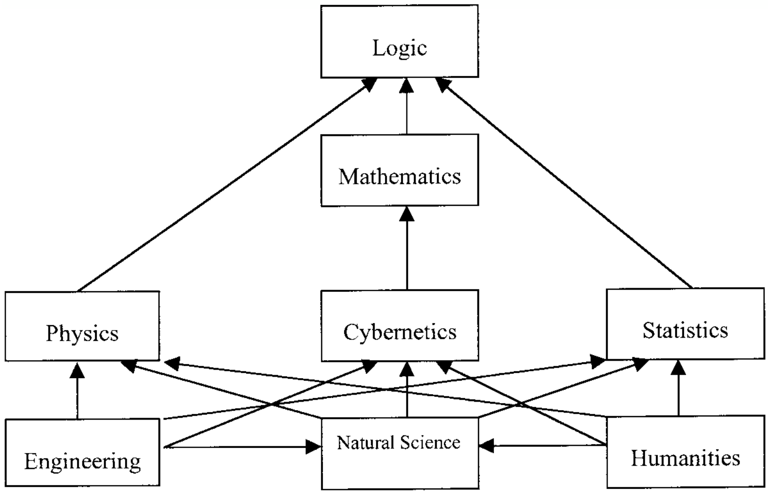

Figure 5.2
The system of relations among the sciences. Adapted from Liapunov, *Problemy teoreticheskoi i prikladnoi kibernetiki.*

in the table.[10] Liapunov often brought a human-size copy of this table with him to his public lectures on cybernetics. In 1956–57 Liapunov and his associates delivered more than a hundred such lectures before various scientific, engineering, and public audiences.[11] (For a condensed version of this table, showing eight methods of analysis, see figure 5.3.)

Evolutionary biologists, geneticists, linguists, physiologists, economists, and computer scientists all found places for themselves in this grand design. The cybernetics movement began to spread over a wide range of disciplines. "Biological cyberneticians" challenged the Lysenkoites in biology; "physiological cyberneticians" opposed the Pavlovian school in physiology; "cybernetic linguists" confronted the traditionalists in linguistics. The opponents of dominant schools in various fields began speaking the language of cybernetics.

The Council on Cybernetics as an Institutional "Umbrella"

To implement his far-reaching program of the "cybernetization" of Soviet science, Liapunov took steps to institutionalize cybernetic research in the Soviet Union. He thought that a loosely organized scientific council subordinated directly to the presidium of the Soviet Academy of Sciences would

Figure 5.3
Aleksei Liapunov lecturing on cybernetics.

best fulfill the mediating and universalizing mission of cybernetics. At that time, Liapunov was not a member of the Academy and lacked necessary political influence and administrative skills to head such a council, so he asked Academician Aksel' Berg, who had just retired as Deputy Minister of Defense in charge of radioelectronics, to fill that post. Berg agreed, and his strong personality had a decisive effect on Soviet cybernetics.

Aksel' Ivanovich Berg (1893–1979) was born into a prominent noble family in Orenburg; his father was a retired general of the Tsarist army.[12] Berg served in the Imperial Navy during World War I. After the Russian Revolution, he became a submarine commander in the Red Navy. In 1925 he graduated from the Leningrad Navy Academy, specializing in radio engineering. Berg then served in various Navy research institutions, and in 1932 he became the head of the Naval Scientific Research Institute of Communication. In December of 1937, on the wave of the Great Terror, he was arrested on trumped-up charges and thrown into prison. In May of 1940 all charges were dismissed; Berg was released and again appointed to a responsible post. Legend has it that Stalin himself met with Berg and asked him, "Aksel' Ivanovich, what are you doing in jail, while this country needs your service?"[13] In 1943 Berg was appointed Deputy Chairman of the State Defense Committee Council on Radar and Deputy People's Commissar of Electrical Industry of the Soviet Union. He joined the Communist Party in

TASK	DESCRIPTION	MATHEMATICAL APPARATUS	COMPUTER SCIENCE	ECONOMICS
1. Determine information flows	Determine connections with environment and external memory	Observation	Memory allocation	Study the distribution of information that controls the economy (economic documentation)
2. Determine the information code	Determine how information is coded	Statistical and logical analysis, coding theory	Creating a language for task formulation, input, and output	Study the methods of economic information coding
3. Determine the functions of a control system	Setting specific time intervals, determine the functions of a control system	Cybernetic experiment, probabilistic processes	Determine the function of a computer program	Study the functioning of systems that control the economy
4. Study the functioning of a control system	Evaluate the achievement of goals, organization, and communication	Information theory, game and automata theory, operations research	Evaluate the entropy of various task classes and the redundancy of various coding methods; evaluate working time and computer time	Evaluate the amount of information, channel capacity, transmission time, and methods of decision-making and self-regulation
5. Determine the elements of a control system	Determine the elements, study their properties, and classify them by types	Statistical analysis, logical analysis	Determine the classes of operators and develop standard subroutines	Determine the elements of economic processes and the elements of economic regions; use statistics to determine their functions
6. Study the relations among the elements	Determine all the relations essential for the functioning of the system	Cybernetic experiment, graph theory, network theory	Determine the types of relations between different operators	Study the relations among the elements of economic processes and among the elements of economic regions
7. Determine the algorithms of a control system	Determine the (approximate) algorithms of a certain class of control systems	Cybernetic experiment, game theory, theory of algorithms	Develop algorithms of automatic programming and automatic program testing	Develop approximate algorithms for controlling the economy
8. Analysis of a control system	Study the properties of algorithmic control	Information theory, game theory, linear programming	Derive an algorithm from a program; study the completeness of a programming method for a given class	Analyze the control of the economy

1944, and he remained a dedicated communist for the rest of his life. In 1946 he was elected a full member of the Academy of Sciences. In 1953 he became Deputy Minister of Defense, but 4 years later, after a severe heart attack, had to retire for health reasons. In 1957–1960 Berg served as consultant to the Ministry of Defense, and in 1958–59 he headed the Scientific Technical Council of the State Planning Committee on complex mechanization and automation of production.

Berg brought to the cause of cybernetics the same energy and organizational skills that had served him well during the war. In January of 1959

HARDWARE DESIGN	PRODUCTION CONTROL	LINGUISTICS	GENETICS	EVOLUTION-ARY THEORY	NEURO-PHYSIOLOGY
Study the flows of information in a computer	Study the flows of information that controls production		Study the methods of transmitting hereditary information	Study the flows of information that controls evolution	Study the circulation of information in the nervous system and in the receptors
Study the methods of coding numbers and operators in a computer	Study the methods of information coding in production control	Study the methods of linguistic information coding in a computer	Study the methods of hereditary information coding	Study the methods of coding of information that controls evolution	Study the methods of information coding in the nervous system and in the receptors
Determine if the computer func-tions according to design	Determine the function of production control	Study the possibility of machine translation algorithms	Study the ways in which genotype is expressed (phenogenetics)	Study the evolution of populations under specific conditions	Study reactions, reflexes, and behavior of animals
Evaluate the amount of information in the computer and its productivity, and collect operations statistics	Analyze operations, evaluate the amount of information, channel capacity, and information delays	Evaluate the entropy of text classes and information search tasks; evaluate work time and computer time	Evaluate the amount and study the transmission of genetic information, mutation and selection	Evaluate the amount of information that controls evolution; study population dynamics	Evaluate the amount of information and channel capacity of the nervous system; derive its structure from its functioning
Design elements and storage devices	Determine the chain of production control and the functions of its links; develop standardized links	Determine the elementary acts of linguistic algorithms and develop methods of implementation	Determine the biochemical carriers of hereditary information ("the gene problem")	Determine the elementary acts at the basis of evolution ("evolutionary factors")	Determine the elementary constituents of the nervous system, the receptors, and their elementary reactions
Study the interaction of elements	Determine the relations among links and classify them by types	Determine the relations among different operators in linguistic algorithms	Study the structure of genotype, the localization of genes, and the structure of DNA	Study the interactions of different evolutionary factors	Study the relations among individual organs of the nervous system
Give a formal description of the structure and functioning of machines	Develop (possibly, approximate) algorithms for production control	Develop algorithms for machine translation and information systems	Develop an algorithmic description of the transmission of hereditary information	Study the circulation of information that controls evolution	Develop an algorithmic description of the functioning of the nervous system and the receptors
Study statistics of the operation of circuits	Study algorithms of production control; collect production statistics	Experiment with algorithms for machine translation and information systems	Perform a genetic analysis of individual organisms and populations	Study population dynamics and the struggle for existence	Study algorithms of information processing in the nervous system

Figure 5.4
Methods and fields of cybernetic analysis. Adapted from Liapunov and Iablonskii, "Teoreticheskie problemy kibernetiki."

Figure 5.5
Aksel' Berg (standing). Courtesy of Russian Academy of Sciences Archive, Moscow.

the presidium of the Academy of Sciences appointed a commission headed by Berg to examine the prospects of cybernetic research. He mobilized a large group of experts to write a fundamental report on the state of cybernetics. The preparation of the report took 3 months, instead of the allotted 2 weeks, but it produced remarkable results. On 10 April 1959 Berg delivered this report to the presidium of the Academy. The day before, he sent a note to Liapunov, who was the real driving force behind the cybernetics initiative: "Dear Aleksei Andreevich! Please review the text of my report for tomorrow's session of the presidium and make *any* corrections."[14]

In his report, Berg argued that cybernetic research in the Soviet Union was scattered in numerous institutions stretched over vast geographical areas and divided by bureaucratic barriers. He emphasized the need for a central organ that would coordinate this research in the entire Soviet Union. In his unpublished remarks during the session, Berg drew a gloomy picture of the current situation with computerized production control:

There is not a single production control machine working now in the Soviet Union. . . . Electronic machines do not control a single production process anywhere [in the Soviet Union], but they will in the next few years. . . . After a number of institutions were united under a single Special Committee headed by Kalmykov, proper organization of work still has not been achieved. There is no proper contact between [the computer plant in] Penza, [the computer plant in Erevan headed by] Mergelian, and our Moscow institutions, even on specific questions.[15]

The presidium resolved to establish the Scientific Council on Cybernetics and proposed Berg as chairman. Berg frankly admitted that he was no big expert on cybernetics:

I have no idea how I got into the chairman's seat. A. A. Liapunov came and told me that they asked me to be chairman. Nevertheless, I think that a prominent mathematician like Keldysh or someone else should be the head. Although I have worked a lot in this field, there is no reason for me to become the head. I am not quite fit for this; I do not know everything. I would simply say that I do not know enough, and I would not be able to do this job like a specialist would. I am not saying this out of modesty; this is really so.[16]

The president of the Academy, Aleksandr Nesmeianov, replied:

Judging by the state of cybernetics, there are no people around who would know everything, for even the boundaries [of this field] are not clear. I think we should confirm the leadership of the Council as is, and later work will tell.[17]

Berg was appointed chairman, and Liapunov became his deputy.

Berg, with his strong connections and considerable influence in the government and among the military, became a powerful advocate of cybernetics. He secured funding for cybernetics conferences and workshops, obtained permission for the translation of foreign books on cybernetics (particularly Wiener's books), and widely publicized cybernetics in the press, on the radio, and on TV. Berg originally divided the Council on Cybernetics into eight disciplinary sections: mathematics, engineering, economics, mathematical machines (i.e., computers), biology, linguistics, reliability theory, and a "special section" (presumably, military research).[18] Each section coordinated cybernetic research in the corresponding field nationwide. The number of sections grew rapidly. First, philosophy and psychology sections were added, then a transportation section. By 1967 the number of sections had reached fifteen. The structure of the Council fully reflected the mediating role of cybernetics expressed in the charts of the "tree of knowledge" drawn by Soviet cyberneticians.

A large number of research trends marginalized in the strictly hierarchical Soviet academic community found a safe haven in Berg's council.

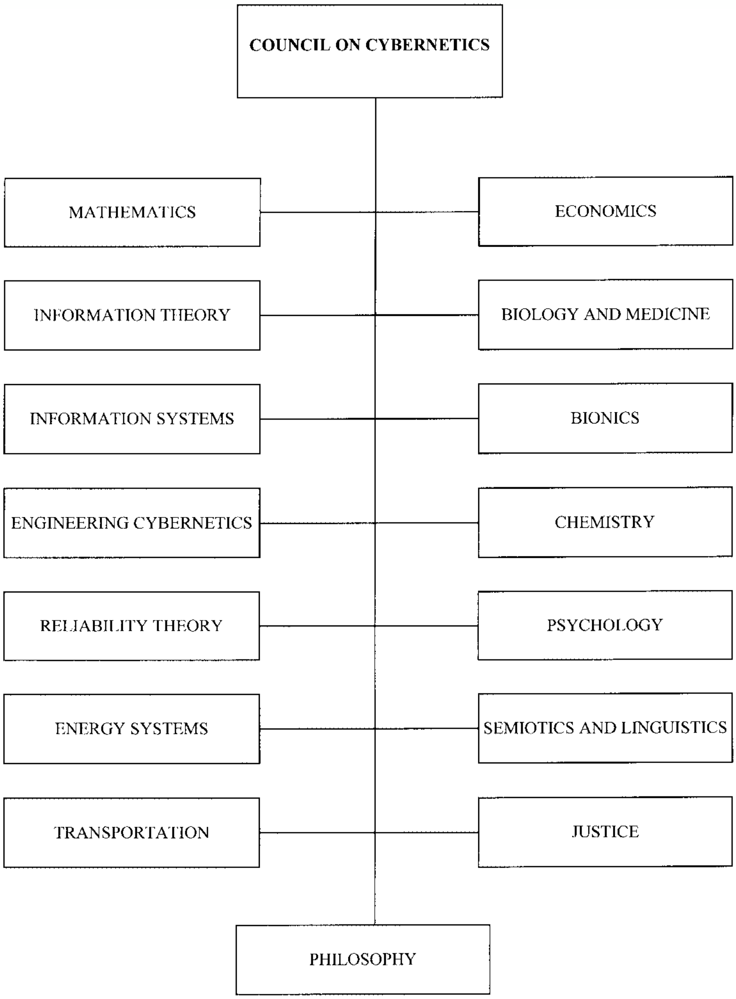

Figure 5.6
The structure of the Scientific Council on Cybernetics of the Soviet Academy of Sciences. Adapted from Berg, ed., *Kibernetiku—na sluzhbu kommunizmu*, volume 5.

Cybernetics served as an institutional "umbrella" for non-Pavlovian physiology ("physiological cybernetics"), structural linguistics ("cybernetic linguistics"), and new approaches in experiment planning ("chemical cybernetics") and legal studies ("legal cybernetics"). With the Council's support, unorthodox researchers were able to publish papers, convene conferences, and effectively legitimize their work as a part of a unified national plan of cybernetic research. Liapunov worked tirelessly to teach scientists cyberspeak and to help them "cybernetize" their fields. One of his disciples has recalled:

> Aleksei Andreevich [Liapunov] used to say that when he contacted scientists from other fields, he spent up to half of the time on the elaboration of a common language. Often the contact would end right there. Once that stage was passed successfully, however, wide possibilities for building up a mathematical theory [for a new field] would open up. [This happened,] of course, when the discipline in question was mature and rich with experimental material. This happened, for example, in mathematical genetics.[19]

Soviet genetics, suffering from the Lysenkoites' onslaught, was probably the discipline most eager to enter a strategic alliance with cybernetics.

Biological Cybernetics: Genes as "Units of Hereditary Information"

After Stalin's death, Soviet geneticists were able to regain some of the positions they had lost after the infamous July-August 1948 session of the Academy of Agricultural Sciences. Lysenko, however, quickly managed to win Khrushchev's personal support, and genetics went "underground" again. As the historian Mark Adams has demonstrated, genetics "hid under protective language: to cognoscenti, such terms as 'radio-biology,' 'radiation bio-physics,' and 'physico-chemical biology' functioned as a kind of protective mimicry, serving as euphemisms for both orthodox genetics and molecular biology."[20] Genetic research was conducted not in biological institutions (which were controlled by the Lysenkoites) but under the roofs of physical and chemical research institutes. One of the code names for genetics in this period was *cybernetic biology*.

Supporters of genetics among the leading Soviet cyberneticians began translating the problem of heredity—the central issue over which Soviet geneticists clashed with Lysenkoites—into the language of cybernetics. In October of 1958, at the All-Union Conference on Philosophical Problems of Natural Science, Aleksei Liapunov and Sergei Sobolev delivered a paper in which they portrayed genetics as an implementation of the cybernetic approach in biology:

> On close examination, it turns out that what is transmitted from the parents to their offspring by inheritance is *hereditary information*. The task of genetics is to study the structure and methods of material coding of this information and the forms of its expression in a new organism in the process of individual development.[21]

When translated into cyberspeak, genetics became an information science. As Sobolev put it: "A living organism develops out of certain embryonic cells in which somewhere lies *information* received from the parents' organisms. This is not physics, this is not physiology; this is the science of the transmission of information."[22]

Liapunov and Sobolev also translated some of the postulates of Lysenko's doctrine into the language of cybernetics, only to show that it failed the cybernetic test:

> The thesis . . . that predominantly favorable traits are transmitted by inheritance requires, to be firmly established, the existence of a flow of hereditary information from the organisms of the offspring to the organisms of the parents. The existence of such a flow, however, seems quite problematic. . . . In the same way, the claim of the inheritance of acquired traits is equivalent to the assertion that there exists a flow of information coming into embryonic cells about the structure of the organism as a whole or its separate organs. . . . The fact is that the flow of hereditary information, traveling from an organism as a whole to its embryonic cells, lies unknown. . . . On the other hand, the data of classical genetics fully correspond to the ideas advanced in cybernetics.[23]

Liapunov became the head of the Biological Section of the Council on Cybernetics; as the editor of the series *Problemy kibernetiki*, published under the Council's auspices, he opened a regular rubric, "Control Processes in Living Organisms," in which he published works on genetics. In particular, Liapunov helped his close friend Nikolai Timoféeff-Ressovsky, a leading specialist in radiation biology, to resume active research and publications after returning from Stalinist labor camps. Timoféeff-Ressovsky's first lecture after his return to Moscow was given at an informal gathering in Liapunov's apartment.[24] The Lysenko clique shunned Timoféeff-Ressovsky, and cautious editors of biological journals controlled by the Lysenkoites turned down the first article he wrote after his return. Thanks to Liapunov's efforts, however, this article, written in collaboration with the geneticist Raisa Berg, appeared in the fifth volume of *Problemy kibernetiki* in 1962.[25] To justify this publication, Timoféeff-Ressovsky and Berg injected a few cybernetic terms in their article. They wrote, for example: "Genotype is a control system that determines the ontogenesis of living organisms and at the same time it is a code of hereditary information, which is transmitted from generation to generation."[26] In 1959–1967 Timoféeff-Ressovsky published seven articles in *Problemy kibernetiki*. In 1958 Raisa Berg organized an interdisciplinary seminar on "Cybernetics and Genetics" at Leningrad University. She later recalled: "Cybernetics, biochemistry, biophysics, mathematical methods in biology, systems theory—all of that was now [in Khrushchev's time] possible, and the languages of these sciences became the Aesopian language of genetics. A 'unit of hereditary information' sounded less anti-Lysenkoist than a 'gene.'"[27]

The strategic alliance between genetics and cybernetics did not escape the attention of the Lysenkoites. They counterattacked, accusing geneticists of the frivolous use of the language of cybernetics. In early 1962 the Lysenkoites submitted to the State Publishing House of Physical and Mathematical Literature a highly negative 20-page review of biological articles published in *Problemy kibernetiki.* According to this review, cyberneticians had interpreted the notion of information too broadly and had illegitimately extended this notion to biology, which had resulted in grave ideological mistakes:

> The volumes of *Problemy kibernetiki* became a "mouthpiece of anti-Michurinism." . . . As an example of "information," [cyberneticians] point out the influence of the environment on the organisms of animals and humans. If so, then the technical meaning of the term *information* in cybernetics is lost. . . . The attempts to view any communication as [the transmission of] information can only be interpreted as the intentional or unintentional ambition to supplant dialectical materialism with cybernetics. . . . If a hierarchy of control exists [in nature], then the question inevitably arises: Who is the chief controller? This can only be a force that does not depend on anyone or anything, in other words, a god. . . . Thus, in accordance with the logic of any idealistic trend [in philosophy], the conception of "controllers" of life phenomena leads to popery.[28]

The review ended with a suggestion to remove Liapunov from the editorship, prohibit the publication of biological articles in *Problemy kibernetiki*, and submit such articles instead to biological journals, conveniently controlled by the Lysenkoites. Alarmed by such serious charges, the director of the publishing house threatened to suspend the publication of biological articles in *Problemy kibernetiki* until the matter was resolved.[29]

Cyberneticians quickly mobilized the scientific community for the support of *Problemy kibernetiki.* Aksel' Berg made several dozen copies of the review and sent them to influential scientists and to the authors of the criticized articles. He received some 40 responses from leading Soviet scientists (including the biologists Vladimir Engel'gardt, Ivan Knuniants, and Vladimir Sukachev, the mathematicians Andrei Kolmogorov, Mikhail Lavrent'ev, and Sergei Sobolev, the physicist Igor' Tamm, and the economist Vasilii Nemchinov) vigorously defending the position of *Problemy kibernetiki.* Raisa Berg, who was among the accused authors, wrote in her response that the cybernetic approach in biology was "confirmed by practice," and defended the use of cyberspeak:

> [The review] speaks with contempt about the cybernetic language used by the authors of the reviewed articles. This contempt is unjustified. One of the goals of *Problemy kibernetiki* is to establish contact among specialists from different fields, which is helped by the elaboration of a common language.[30]

On the basis of these supportive letters, the Council on Cybernetics prepared a detailed rebuttal.[31] Aksel' Berg appealed to the Party Central Committee and to the presidium of the Academy of Sciences. He obtained permission to call a session of the Biological Division of the Academy in April of 1962. This session played a crucial role the legitimization of "biological cybernetics." A broad range of topics, from the "processing of information by the brain" to "self-regulation of processes in cells," were discussed. Berg opened the session, calling upon the participants to find "an optimal form of interaction between the possibilities of cybernetics and the needs of biology."[32] Academician Vasilii Parin—a full member of the Academy of Medical Sciences and the head of the medical section of the Council on Cybernetics—called on his colleagues to "work hard to prepare a large-scale introduction of cybernetics in biology, to redirect our thinking toward the cybernetic examination of biological issues."[33] At this session, the Lysenkoites were unable to provide any open opposition to "biological cybernetics." It was hardly coincidental that just a few days later, at the Party Central Committee's Plenary Session on Agriculture, Trofim Lysenko asked to be relieved of his duties as president of the Academy of Agricultural Sciences for reasons of ill health.[34] The cyberneticians' victory was far from complete: the Biological Division of the Academy remained under the control of the Lysenkoites. In their own disciplines, however, cyberneticians, mathematicians, computer scientists, physicists, and chemists could now safely shelter non-Lysenkoist biological research.

The Mathematical "Axioms of Life"

Soviet cyberneticians now viewed living organisms as belonging to their own professional domain and no longer to the exclusive realm of the life sciences. A new, cybernetic approach to biology, with its alluring promise of creating "thinking machines," acquired wide popularity among the young generation of Soviet scientists. In April of 1961, in a public lecture on

"Automata and Life" before a crowd of 1,000 that filled Moscow University's largest hall, Kolmogorov proclaimed:

> If such qualities of a material system as "being alive" or "capable of thinking" are defined in a purely functional way (for example, any material system with which it is possible to discuss meaningfully some problems of contemporary science or literature will be called a "thinking system"), then one would have to admit that in principle living and thinking beings can be *created artificially*. . . . I belong to the clan of those reckless cyberneticians who see no principal limitations on a cybernetic approach to the problem of life, and believe that one can analyze life in its entirety, including all the complexity of the human mind, with cybernetic methods.[35]

Soviet cyberneticians believed that cyberspeak was *the* language of science, and that rejecting this language meant giving up a scientific approach. At the 1958 philosophical conference, one Lysenko supporter accused Liapunov and Sobolev of reducing the notion of life to a circulation of information and argued that this transfer of terminology from one field to another was illegitimate.[36] Sobolev sharply replied that if one did not describe heredity as transmission of information, the only alternative would be to appeal to divine providence.[37]

Liapunov similarly understood the anthropomorphic terms of cybernetics as more than metaphors. He suggested calling any system that was highly stable and that maintained its stability by processing information encoded on a molecular level "alive." In his view, what made a system alive was not the material of which it was made, be it protein or DNA, but the organization and function of its elements.[38] In a 1962 joint article with the biologist Andrei Malenkov, Liapunov attempted to translate basic concepts and laws of genetics into the language of set theory, giving formal definitions of "intuitive" genetic concepts and strict mathematical formulations of the "postulates" of genetics.[39] In private correspondence, he described this work as a search for "the axioms of life."[40]

Despite his use of *Problemy kibernetiki* as a publishing venue and his earlier contributions to biophysics that inspired Schrödinger's *What Is Life?*, Timoféeff-Ressovsky remained somewhat skeptical about the revolutionary power of cyberspeak. He described Liapunov's cybernetics crusade with good humor: "Liapushka is a sweetie. With great enthusiasm, he would carry you along the wrong path; later, upon discovering his blunder, he would carry you along another path with no less enthusiasm than before, and this new path would be equally wrong."[41] Teasing Liapunov, Timoféeff-Ressovsky used the term *cybernetics* in their private letters in the sense of *confusion* or *mess*; he once described his having put a letter in the wrong envelope as a "complete cybernetics."[42] "Anybody who met with mathematicians more or less regularly," joked Timoféeff-Ressovsky, "can easily imagine the catastrophic picture of the world at the moment when our life and activity are mathematized."[43]

Despite his skeptical attitude, Timoféeff-Ressovsky's involvement in the cybernetics movement profoundly influenced his own research agenda. Timoféeff-Ressovsky did not merely insert a handful of cybernetic terms into his papers to get them published in *Problemy kibernetiki*; he took seriously Liapunov's call for "precise definitions" of biological concepts, and he made systematic attempts to reformulate biological theories in an "exact language" specifically "for cyberneticians." In a private letter to Liapunov in October of 1957, Timoféeff-Ressovsky wrote:

> I sat down and wrote for you, cyberneticians, [an article titled] "Microevolution." I tried, on the one hand, to cover everything essential, and on the other, to be brief. It came down to 33 paragraphs in an aphoristic-axiomatic style. It came out not bad, I think, quite original and different from other writings on evolution. All basic definitions seem to be sufficiently brief and rigorous.[44]

A few weeks later, Timoféeff-Ressovsky wrote to Liapunov about his intention to develop a set of strict definitions for the major concepts of genetics, in the same "aphoristic-axiomatic style," specifically "for cyberneticians and mathematicians."[45] While ridiculing the universalistic pretensions of cybernetics, Timoféeff-Ressovsky believed that cybernetic modeling could be very helpful in the study of specific biological systems. "Perhaps it would be better [for cyberneticians] to refrain from solving all global problems," he argued, "but instead jointly [with biologists] to attempt the construction of mathematical and computer models of simplified biocenological systems."[46] Timoféeff-Ressovsky wrote to Liapunov that the task of elaborating the basic principles of biological experiment would be "most suitable for mathematicians with a cybernetic slant."[47]

Liapunov and Timoféeff-Ressovsky saw their friendship as the starting point for a full-scale collaboration between cyberneticians and biologists. They believed that cybernetics not only supplied methods for "mathematical biology" (the construction and analysis of mathematical models of biological phenomena) but also served as the basis for a new approach to theoretical biology. Using the cybernetic notions of system and organization, Timoféeff-Ressovsky classified living nature into systems arranged

Figure 5.7
Nikolai Timoféeff-Ressovsky and Aleksei Liapunov in Miassovo. Courtesy of Natal'ia Liapunova.

hierarchically into four "levels of organization"—the cell, the organism, the population, and the biocenosis—with each system functioning as an element of a higher-level system.[48] Liapunov, in turn, interpreted these systems as cybernetic "control systems," each with its own mechanism of control and information exchange.[49] He argued that a unified theoretical perspective on the problems of life could be achieved "from the viewpoint of the theory of systems and control processes, that is, from the viewpoint of cybernetics."[50] In this case, cybernetics was called not so much to solve particular biological problems as to provide a discursive bridge between various biological disciplines. Cyberspeak was to become a common language for all biological disciplines, from molecular biology to developmental biology to evolutionary biology to ecology.

Liapunov's appeal was heard by the leading evolutionary biologist Ivan Shmal'gauzen, a prominent target of Lysenko's attacks at the July-August 1948 session of the Academy of Agricultural Sciences. By interpreting biocenosis as a control device with respect to populations, and thus representing evolution as regulated rather than a random process, Shmal'gauzen was effectively "translating Darwin's theory into the language of cybernetics."[51] In their introduction to a collection of Shmal'gauzen's papers on "biological cybernetics," Liapunov and Raisa Berg wrote:

> Shmal'gauzen did not stop at discovering the universality of the feedback principle at all levels of the organization of life, starting from the molecular level and up to the organism as a system. He also deserves credit for studying this principle at such levels of the organization of life in which the organism is included as a component, that is, at the levels of population and biocenosis. Evolution itself has appeared before us as a process regulated by feedback.[52]

While Liapunov attempted to translate classical genetics into cyberspeak, and Shmal'gauzen did the same for evolutionary theory, Liapunov's disciple, geneticist Vadim Ratner, wrote a dissertation on "genetic control system," bringing molecular biology under the umbrella of cybernetics. He introduced the notion of "genetic system" as "a set of cellular and molecular structures and mechanisms participating in the recording, transmission, implementation, and processing of genetic information," and defined the gene as a "compact set of hereditary memory locations (genetic elements) that encode discrete . . . genetic functions."[53] He considered genetic systems as "control systems" in Liapunov's sense, and described their operation in terms of memory mechanisms, information flows, and coding methods.[54]

Although some "biological cyberneticians" felt that the use of cyberspeak could sometimes be excessive, the cybernetic legitimization of genetics in the face of Lysenko's strong opposition seemed more important than putting exact limits on the cybernetic approach. Academician Vasilii Parin, who succeeded Liapunov as chairman of the Biology Section of the Academy Council on Cybernetics, warned that one "should not abuse cybernetic terminology," but in the same breath he described cells, organs, and organisms as "cybernetic systems" and called for the "mathematization and algorithmization of major biological parameters."[55]

The grand project of the "cybernetization" of Soviet science was sustained not only by the popular appeal of cyberspeak but also by the strategic advantage a marginalized scientific theory acquired when it was translated into the language of cybernetics. In this way, cybernetics helped legitimize not only genetics but also non-Pavlovian "physiology of activity."

Physiological Cybernetics: The Brain as a Subject of Technology

Cybernetics entered Soviet academic discourse at the time of a sharp debate between the orthodox followers of Ivan Pavlov's physiological school and their opponents. Cybernetics opened new vistas for physiological research, for it dealt with purposeful behavior, which had been bracketed out by the dominant dogmatic version of the Pavlovian doctrine. Cybernetics suggested parallels between nervous impulses and information exchange, between performing a movement and executing a program, and between thinking and computing. Cybernetics-minded physiologists were fascinated with the complexity and subtlety of the new man-machine metaphors. Orthodox Pavlovians, however, quickly dismissed such analogies as "mechanistic." To cyberneticians, on the other hand, such cybernetic self-regulating devices as computers and servomechanisms seemed much more appropriate as models for physiology than the telephone switchboard Pavlov had used as a metaphor for higher nervous activity. The struggle between orthodox Pavlovians (adherents of reflex theory) and "physiological cyberneticians" (advocates of circular physiological mechanisms) shaped the Soviet debate over the validity of cybernetic models in physiology.

One of the central tenets of cybernetics was the analogy between the computer and the human nervous system. In cyberspeak, both were described as information-processing devices. The analogy went both ways: from physiology toward technology (when neurophysiological knowledge was applied to build efficient devices) and from technology toward physiology (when technical terms and mathematical formalisms were employed to describe physiological processes). Mathematicians and engineers borrowed such common physiological and psychological concepts as *memory*, *homeostasis*, *reflex*, and *purpose* and attached strict technical meanings to them. Physiologists, on the other hand, reversed cybernetic metaphors and began using such concepts as *information*, *programming*, and *feedback* in a physiological context.

The prominent non-Pavlovian physiologist Nikolai Bernshtein was one of the first to take advantage of cyberspeak. While the Pavlovian school eschewed the notion of purpose, considering it purely psychological and therefore "unscientific," Bernshtein made that notion the centerpiece of his theory. He argued that the rigid Pavlovian scheme of conditional reflexes was based on experimental studies of animals confined in cages and subjected to measured stimuli, and that such studies depicted the organism as merely responsive, or "passive." He called for the creation of "physiology of activity," which would study purposeful behavior. Bernshtein insisted that a scientific physiological study of purposeful behavior was possible if the notion of purpose was conceptualized as "material codes in the central nervous system . . . such that both forecasts and programs of the future may be programmed into the nervous system."[56] In 1957 he published an article in which he systematically translated his theory of locomotion into the language of cybernetics. Instead of the "construction of movements," he spoke of "control" and "programming"; nervous impulses became "informations" (plural), and the motor apparatus was described as a self-regulating servomechanism.[57] The use of cybernetic instead of psychological terms made it possible to avoid accusations of "idealism" and "vitalism" such as had been brought against Bernshtein before. Bernshtein's "physiology of activity," it seemed, could only be written in the language of cybernetics.

Bernshtein borrowed his new vocabulary from Wiener's *Cybernetics*, but conceptually he did not depend on Wiener. Bernshtein found Wiener's model of purposeful behavior motivating, but he revised it immediately. Bernshtein argued that the goal of action was encoded in the nervous system as the model of a future event, and that purposeful behavior was oriented toward this model rather than toward an actual target.[58] Bernshtein eventually arrived at a comprehensive model of the organism as a self-regulating machine that received information from the external world, encoded it in a model, programmed its actions, and constructed its movements.[59]

Unlike Wiener, Bernshtein made a clear distinction between simple adaptation to the environment and purposeful activity aimed at changing the environment. The former could be achieved by means of Pavlovian reflexes; the latter could not be reduced to reflexes. To explain the mathematical meaning of this distinction, Bernshtein employed the conceptual apparatus of "well-organized functions" elaborated by mathematicians Izrail' Gel'fand and Mikhail Tsetlin of the Applied Mathematics Division.[60] Gel'fand and Tsetlin called multi-variable functions "well-organized" if their arguments could be separated into "essential" and "non-essential" variables. The former determined the main characteristics of a function (its overall shape and its extremes); the latter could cause only abrupt local changes and discontinuities but exerted little influence on the function as a whole. Bernshtein argued that the coordination of movements (for example, writing) and the construction of models in the brain in the process of perception could both be described by those "remarkable functions." A handwriting style, for example, could vary in its "non-essential" parameters depending on the position of a hand, but it still possessed "essential" features characteristic of a particular person. Bernshtein argued that living organisms acted just like "well-organized" mathematical functions:

> It has already been observed how differently an organism behaves under the influence of its surroundings with reference to essential and non-essential variables. As regards the latter type, it is reactive and, so to speak, yieldingly adaptable: if one leaf on a tree receives more food than another, then that leaf grows more vigorously than the other one. . . . But essential characteristics of structure and shape such as those which determine the plan of the flower . . . are only relinquished by an organism if it is subjected to very violent interference. . . . Thus the function, that is the organism, may be said to be reactive as far as its non-essential variables are concerned, but highly non-reactive, or active, with regard to its essential ones.[61]

By this distinction, Bernshtein also illustrated the limited applicability of the Pavlovian model (reactions of a passive organism) relative to his own model (actions of an active organism).

Bernshtein argued that such concepts as equilibrium and homeostasis were applicable only to non-essential variables. When, on the other hand, external influences affected an organism's essential variables, the organism would "respond with the most active counteraction and not yield without serious struggle, sometimes with the help of a counterforce, sometimes with evasive tactics."[62] Somewhere between the lines, Bernshtein may have reflected on the passive social tactics of the conformists who were "yieldingly adaptable" and looked for an "equilibrium" with the authorities. Personally, Bernshtein saw his mission as "liberating the organism from the role of a 'reactive automaton,'"[63]—in other words, liberating Soviet physiology from Pavlovian dogmas. Perhaps he used cyberspeak as a "counterforce" or an "evasive tactic" to defend his "essential variables."

Supporters and opponents of "physiological cybernetics" clashed in an open debate at the All-Union Conference on Philosophical Questions of the Physiology of Higher Nervous Activity and Psychology held in Moscow in May of 1962.[64] Speaking at the conference, Bernshtein argued that reflex theory, in both Cartesian and Pavlovian versions, treated the organism as a "highly organized reacting machine."[65] He contended that initial perceptions did not simply launch corresponding reflexes but were transformed by mathematical "operators" to form a well-structured mental "model of the world." Orthodox Pavlovians responded with an old argument against the use of mathematics in the life sciences; they charged that Bernshtein's "models of the world" were "detached from their material substance, that is, the nervous structures." Alluding to Lenin's "classical" critique of the "idealistic" interpretations of relativity theory in which "matter disappeared and only equations remained," one of the conference participants argued that in Bernshtein's theory "physiological processes in the brain are supplanted by the technology of mathematical thinking," "reflex mechanisms of the functioning of the nervous system totally disappear" and "only mathematical transformations remain."[66] While Wiener claimed that the cybernetic model of purposeful behavior had bridged the gap between mechanical causality and teleology, Soviet critics accused Bernshtein both of "mechanicism" (i.e., reducing everything to mechanical causality) and of teleology (which the critics closely associated with vitalism and idealism). Criticizing Bernshtein's notion of the "inborn program of development," one speaker asked rhetorically: "Who compiled this program and put it into living matter, like in a cybernetic machine? There is a strong smell of Aristotle's entelechy here."[67]

Cyberneticians provided crucial support for Bernshtein's position. They claimed that the dominant physiological doctrine was inadequate, for it did not provide a clear picture of physiological mechanisms. For example, the engineers Artobolevskii and Kobrinskii argued that contemporary theories of human thinking lacked foundation and were nothing more than conventions. They wrote: "It is necessary to understand how man thinks, to understand the whole mechanism of his thinking in its entirety—to understand and not just agree that we would call thinking such-and-such!"[68] Speaking at the 1962 conference, the leading specialist in pattern recognition, the mathematician Mikhail Bongard of the Institute of Biophysics, argued that Pavlovian reflex theory, if subjected to a cybernetic test, failed to explain pivotal physiological mechanisms, such as learning:

> If you claim that you understand the mechanism of learning, this can easily be checked. Engineers will create elements that would be able to acquire conditional reflexes. Try to assemble from such elements a device that would act expediently in a complex changing environment. I have studied this problem myself and learned that it is hopeless to try to assemble such a device from the elements modeling conditional reflexes.[69]

Bongard argued that reflex theory was clearly not adequate for explaining higher nervous activity. According to the Pavlovian doctrine, a conditional reflex can be established only on the basis of an unconditional one, by means of substituting an unconditional stimulus with a conditional stimulus. Bongard contended, however, that complex reactions, such as solving an arithmetical problem, could not be caused by any unconditional stimulus, and therefore there was nothing to substitute for. "Even a system of very complex conditional reflexes would not suffice to explain the activity of a living organism," he maintained, "in the same way as statics cannot explain the flight of a rocket."[70] Instead, Bongard argued, one must look for a solution by building cybernetic models. He suggested a feedback model of learning, implemented in his original computer program for pattern recognition; this program derived its own rules of classification by "learning" from the existing examples of correct classification.[71]

Physiology was among the first disciplines included by Liapunov in his grand project of the cybernetization of science. Among the specific cybernetics problems in the field of physiology, he listed the following:

(1) the study of information flows in the nervous system and the receptors;
(2) the study of the methods of encoding information in the nervous system and the receptors;
(3) the study of reactions, reflexes, and behavior of animals;
(4) the evaluation of the amount of information and the channel capacity of the nervous system;
(5) the study of hierarchical functioning and collective behavior;
(6) the algorithmic description of the nervous system and the receptors.[72]

To set an example of a successful translation of physiological concepts into cyberspeak, Liapunov offered a stochastic algorithm modeling the acquisition of a conditional reflex.[73]

On the pages of *Voprosy filosofii*, the control engineer Gal'perin announced that "automatic control systems in today's machines fulfill the function of a nervous system."[74] He claimed that automatic control devices were already capable of demonstrating unconditional reflexes, since they gave preset responses to diverse inputs. He further argued that conditional reflexes, too, could, in principle, be reproduced in modern control devices. "Taking the exact sense of Pavlov's definition [of the conditional reflex]," he wrote, "it is impossible to make a distinction between the mechanism of the conditional reflex and the functioning of an automatic control system."[75] He concluded that automatic control devices were bringing about a "reevaluation of physiological values."[76] This cybernetic "expansionism" left little room for non-cybernetic physiology. Paraphrasing Pavlov's contention that the human brain, which had created natural science, was itself becoming a subject of natural science, Gal'perin wrote: "The human brain, which has created technology, now, in control devices, is itself becoming (in its simplest functions) a subject of technology."[77] If the human brain became a subject of technology, what would be the subject of neurophysiology?

Speaking at the 1962 conference, Bongard announced that cybernetic models would henceforth be "unrelenting examiners" of physiological theories and hypotheses. When cyberneticians assumed the role of judges of physiological theories, the orthodox Pavlovians had little chance to retain their dominant position in the physiology community.

"Man Is the Most Perfect of All Known Cybernetic Machines . . . "

Soviet "physiological cyberneticians" aimed at a comprehensive cybernetic modeling of physiological processes. Bernshtein, for example, criticized Western cyberneticians' experiments with devices simulating individual physiological acts, and called for creating universal cybernetic models that would cover a wide range of physiological functions. A cybernetic model would adequately represent human physiological mechanisms, he argued, only if it demonstrated human-like variations of quality and accessibility over a wide range of functions.[78] Cyberneticians therefore aspired to a complete translation of physiological terminology into cyberspeak. Sobolev, in particular, argued that there was no limit to the applicability of notions of cybernetics to living organisms:

> In cybernetics, a machine is defined as a system capable of accomplishing actions that lead to a certain goal. Therefore, all living organisms, and human beings in particular, are in this sense machines. Man is the most perfect of all known cybernetic machines. . . . There is no doubt that all human activity manifests the functioning of a mechanism, which in all its parts obeys the same laws of mathematics, physics, and chemistry, as does any machine.[79]

Pavlovian physiologists tried to oppose this trend, but they could hardly resist the thrust of the cybernetics wave. For example, Iurii Frolov argued that a machine "lacks feedback that exists between man and the constantly changing social environment" and therefore cannot think.[80] Ironically, while trying to show the limitations of man-machine metaphors, he himself borrowed the term *feedback* from the language of cybernetics. Man-machine metaphors permeated public discourse so deeply that it proved impossible to step outside cyberspeak even for the sake of criticizing this metaphorical language.

The use of cyberspeak among reform-minded Soviet physiologists was becoming truly pervasive. In the contemporary scientific literature, one finds many such examples, such as the following:

> Speaking in the language of mathematical cybernetics, the synapse is characterized by indefinitely wide probabilities of change.[81]
>
> If we use the cybernetic language, we can speak of a gigantic amount of information passing through generations in the course of morphogenesis.[82]

Bernshtein argued that cyberspeak played a more important role in the latest revolutionary transformation of the life sciences than new scientific instruments or computing devices:

> The main reason why mathematics and biology finally began to find a long-awaited common language was undoubtedly the formation and elaboration of new concepts and generalizations. Such concepts include *control, information, coding, communication,* and *multi-level regulation,* in other words, precisely the circle of ideas that is covered by the term cybernetics.[83]

The reversibility of man-machine metaphors facilitated an exchange of ideas between cybernetic physiology, engineering, and mathematics. Bernshtein wrote, for example, that an organism encountering a "dynamically variable" situation would have to make "a probabilistic forecast": "To use a metaphor, we might say that the organism is constantly playing a game with its environment, a game where the rules are not defined and the moves planned by the opponent are not known."[84] The mathematician Mikhail Tsetlin, a close friend of Bernshtein, translated this idea into the language of game theory.[85] He studied a particular type of game in which stochastic automata did not "know" the pay function of their game in advance and had to develop their tactics in the course of the game. Tsetlin informally compared the tactics of a simple automaton facing complex environment to the behavior of "a little animal in the big world."[86]

Tsetlin studied finite automata, the same simple mathematical objects that attracted the attention of John von Neumann, but focused specifically on their "collective behavior." Tsetlin proposed a general mechanism by which the combined action of a large number of primitive automata, each following very simple rules, resulted in expedient actions of the system as a whole. The key to this mechanism, he argued, was "the principle of least interaction": all parts of the system "strove" to minimize their interaction with other parts and with the system's environment. This mechanism greatly simplified the function of control, since the actions of each part no longer had to be directed from one center. Given a "pay function," individual automata figured out their own best strategies, which resulted in the overall optimal strategy for the system. Neurophysiologists usually assumed that various nervous centers in the brain coordinated their activity by means of a complex system of connections. Tsetlin argued that, overall, expedient behavior could be achieved even if these centers "interacted" only by means of observing changes in their environment:

> At each moment, the subsystem solves its own "particular," "personal" problem—namely, it minimizes its interaction with the medium; therefore, the complexity of the subsystem does not depend on the complexity of the entire system. . . . Our mathematical models allow us (to a certain degree) to imagine the interaction of the nerve centers without considering the complex system of links and the coordination of their activity.[87]

The works of Tsetlin and Bernshtein straddled the fence between mathematics and neurophysiology. They did not easily fit in the accepted frameworks for either discipline. They found a niche in cybernetics. Tsetlin became the first "Learned Secretary" of the Academy Council on Cybernetics on the day of its inception. Both Tsetlin and Bernshtein actively published their results in *Problemy kibernetiki*, edited by Liapunov.

Legitimized as "physiological cybernetics," Bernshtein's methods of the study of locomotion were widely applied in ergonomic studies and in the training of cosmonauts. For example, using Bernshtein's methods, his student Levan Chkhaidze worked out a quantitative measure of the coordination of motor actions and was able to prove that this coordination would be quickly restored after some initial disturbance caused by changes in the gravitational field. This result dispelled some fears among Soviet space researchers about the reliability of cosmonauts' motor actions in the conditions of weightlessness.[88] In 1967 a collection of Bernshtein's articles was translated into English[89] and propagandized by a group of physiologists at Haskins Laboratories in New Haven, Connecticut; his work "rapidly became a sort of bible for those who considered him as a 'laboratory genius.'"[90] In 1984 leading Western specialists called Bernshtein "a precursor of cognitive neurobiology."[91]

Soviet cyberneticians believed that mathematical modeling and computer simulation would reveal the underlying mechanisms of all brain functions, including linguistic abilities. The Council on Cybernetics set up a Linguistics Section, which provided a safe haven for innovative research marginalized by the mainstream Soviet linguistics.

Cybernetic Linguistics: Making the Study of Language an "Exact Science"

In the mid 1950s, a new generation of Soviet linguists, repelled by the opportunistic turns taken by the linguistics establishment during the period of Marrism and during the subsequent anti-Marrist campaign, was searching for a new research paradigm. The linguist Viacheslav Ivanov, then an assistant professor at Moscow University, later recalled: "We were tired of the phraseology of the official philosophy. We wanted to deal with precisely defined concepts and with terms that were defined through rigorously described operations."[92] The linguist Isaak Revzin, of the Institute of Foreign Languages, expressed "distrust of all kinds of sociological phraseology and linguistic journalism" and called for the elaboration of "objective, exact methods" of linguistics.[93] The cultural historian Iurii Lotman, of Tartu University, admitted that his "tiredness of the verbiage that is sometimes introduced under the name of science" drove him to use "exact methods" of study.[94] These scholars saw the sought-after "exact language" of science in the formal language of cybernetics and information theory.

A major part in the promotion of cybernetic ideas in Soviet linguistics was played by Roman Jakobson, the Russian-born American linguist whose works were discussed in chapter 1. His early involvement in the Formalist movement in the 1910s and the 1920s was also characterized by the search for "precise terminology," in contrast to the rhetorical trend that dominated the humanities at the time. "Until recently, the history of art, particularly that of literature, has had more in common with causerie than with scholarship," Jakobson wrote in 1921. "In causerie we are slipshod with our terminology; in fact, variations in terms and equivocations so apt to punning often lend considerable charm to the conversation."[95] To turn linguistics into science, Jakobson adopted the structural approach, which, he argued, was dominating contemporary science. Like "any set of phenomena examined by contemporary science," he argued, language must be "treated not as a mechanical agglomeration but as a structural whole," and the basic task of structural linguistics was "to reveal the inner, whether static or developmental, laws of this system."[96] In the late 1940s, Jakobson joined the cybernetics circle around Norbert Wiener and Claude Shannon, and soon he brought the gist of cybernetic innovations to the Soviet Union. In May of 1956, during his first visit to Moscow after his emigration, Jakobson met informally with a number of young Soviet scholars, including Ivanov, and discussed applications of information theory to the analysis of language.[97]

In June of 1956, soon after Jakobson's visit, Ivanov and another young assistant professor at Moscow University—the mathematician Vladimir Uspenskii, a former student of Andrei Kolmogorov—decided to organize an interdepartmental research seminar on mathematical linguistics. They drafted a list of seminar discussion topics that included statistics, mathematical logic, machine translation, information theory, mathematical definitions of grammatical categories, and the "mathematization of language."[98] Uspenskii later recalled that he and his colleagues were driven by "the irrational urge to find in language precise laws that would resemble mathematics in their rigor."[99] An agenda for the "mathematization" of Soviet linguistics was set.

The seminar, which opened in September of 1956, attracted a mixed audience of mathematicians and linguists—unusual for both disciplines. At the first session, Uspenskii proposed to discuss two problems formulated by Kolmogorov himself: how to give formal definitions of the grammatical case and of the iambic poetic meter. It was no accident that the seminar started off with definitions: mathematicians were not content with the intuitive meanings of linguistic categories, to which linguists were accustomed. The mathematicians proudly claimed that striving for unambiguous definitions was one of the "specific traits of the mathematical style of thinking," and they insisted that a mathematician in linguistics "plays the role of a litmus test: if a definition satisfies the mathematician, then it must satisfy everyone."[100] In 1957 Uspenskii taught an extracurricular mathematical course for linguists in which he emphasized such principles of mathematical thinking as "clear explication of major abstract concepts, delineation between the definable and indefinable, [and] between the deductive and the inductive"—the principles that, in his view, linguistics students particularly lacked.[101]

Cybernetics, with its promise of making scientific knowledge objective by translating it into the "exact" mathematical language of computer algorithms, naturally appealed to the young generation of Soviet linguists. In the mid 1950s, the forbidden fruit of cybernetics, still labeled in the popular press a "reactionary pseudo-science," seemed particularly attractive to those dissatisfied with both political and scientific orthodoxy. In the autumn of 1954 Aleksei Liapunov's lecture on cybernetics at the Philology Faculty of Moscow University ended with a scandal: Liapunov was ejected from its room for sowing ideological heresy. This only added to Liapunov's popularity, and soon he was asked to speak on the prospects of machine translation at the Moscow State Pedagogical Institute of Foreign Languages. Revzin, who attended the lecture, later recalled:

> He did not talk much about machine translation, but said only a few words in the end. [Instead] he spoke of Cybernetics (I heard this word for the first time!) from a broad philosophical perspective. The romance of the earliest stories of the fantastic prospects of cybernetics . . . shrouded the figure of Liapunov, who already looked like a preacher, in an aura of a pioneer. He linked the question of translation, which had been haunting me since my student years, with the entire host of complex human problems, from genetics and medicine to control, and this convinced me right away. I instantly decided that this was the way to go.[102]

Inspired by the promise of cybernetics, linguists began translating their problems into cyberspeak. They viewed the computer processing of texts as a model for understanding linguistic phenomena. In a 1961 article on "linguistic problems of cybernetics," co-authored with the prominent linguist Sebast'ian Shaumian, Ivanov argued that "the parts of the brain engaged specifically in the analysis of language can be compared to those specialized [computing] machines that are designed for linguistic analysis."[103] Ivanov also used machine translation as a model for analyzing various deviations from the norm in the human use of natural language:

> One can compare deviations from the linguistic norm that occur in machine-produced texts . . . to non-normalized human discourse (such as dialects, children's talk, or poetic speech) or to pathological deviations from the linguistic norm (aphasia). In the case of aphasia, one finds errors linked to the limitations on the capacity of short-term memory, which is typical of machines. . . . The literal interpretation of idioms, often observed in aphasia, is comparable to similar mistakes in machine translation, when each word in an idiom is simply linked to a corresponding dictionary entry, but this entry does not mention that this word may be part of an idiom.[104]

Ivanov and Shaumian called for a far-reaching reform of linguistics on the basis of mathematical formalisms and computer modeling. A new discipline of structural linguistics, they argued, must be built as an "abstract theoretical discipline studying the construction of formal models of language."[105] Ivanov and Shaumian viewed cyberspeak as a discursive "bridge" between structural linguistics and cybernetics:

> The basis of cybernetics is the study of the laws of transmission and processing of information. . . . In the transmission of information, it is often necessary to convert information from one sign system into another, that is, from one code into

another. This type of conversion is called coding. Any code is a language, and coding is nothing else but translation from one language into another. Therefore, studying codes and coding is a linguistic problem, and the theory of codes and coding is a linguistic theory. . . . It is precisely the concepts of code and coding that serve as a bridge between structural linguistics and cybernetics.[106]

While Jakobson viewed natural language as a code, and therefore included linguistics under the umbrella of information theory, Ivanov and Shaumian regarded any code as a language, and thus portrayed information theory as part of linguistics. In any case, cyberspeak as a mediating language seemed to be applicable both to the human use of natural language and to the computer processing of texts. Ivanov and Shaumian proclaimed that structural linguistics belonged to the "complex of sciences united by cybernetics into an integrated ensemble."[107]

Fashioned as "mathematical" or "cybernetic" linguistics, structural linguistics as a discipline claimed its conceptual independence from traditional linguistics. "Mathematical linguistics is a mathematical discipline," Liapunov argued. "It has the same relationship to mathematics as does mathematical physics, which borrows its problems from physics and its methods from mathematics. . . . For a mathematician, it is part of mathematics; for a physicist—part of physics."[108] Revzin similarly defined mathematical linguistics as a "mathematical discipline aimed at a humanist subject," and modern structural linguistics as a "humanist discipline, which uses exact methods," and argued that the two overlapped and interacted significantly. In his view, structural linguistics, by using "exact methods" borrowed from mathematics, would incorporate "all the means of exact description of language."[109]

Inspired by mathematicians, structural linguists began to fashion their discipline after axiomatic mathematical theories. At a 1959 conference on mathematical linguistics, Shaumian proposed to reconstruct all of linguistics as an abstract, purely deductive science, whose concepts and laws were to be postulated a priori rather than discovered empirically.[110] In his 1962 book *Models of Language*, Revzin similarly suggested that linguistics be built as a formal axiomatic theory modeled on logic and mathematics:

In its deductive part, Linguistics, it seems, can be constructed just as Logic or Mathematics are constructed; a certain minimal quantity of primary indefinable terms is established, and all the rest of the terms are defined by means of the primary ones. At the same time certain primary statements as to the connections between these terms (axioms) should be clearly formulated and all other statements should be proved, i.e. reduced to certain other statements.[111]

Instead of accepting the dominant view of linguistics as an ideology-laden humanist discipline, Soviet structural linguists preferred to think of themselves as natural scientists. "We were attracted by the precision of formulations [in mathematical linguistics]," recalled Ivanov. They believed that precisely formulated linguistic hypotheses, unlike claims made in the humanities, were verifiable: "In linguistics one could compare a theoretical statement with empirical data and to either confirm or reject it."[112] In their 1961 article, Ivanov and Shaumian argued that, through an alliance with cybernetics, structural linguistics would become an "exact science":

> The emergence of structural linguistics signifies a revolution in the study of language, resulting in its transformation from an empirical and descriptive field of knowledge into an exact one. Through structural linguistics, the study of language enters the family of exact sciences, such as physics, chemistry, and biology.[113]

By adopting cyberspeak, structural linguists began to associate scientific objectivity with formal definitions and with mathematical and logical models. Shaumian maintained that structural linguistics must be based on the methodological principles "imperative for any scientific theory as a logical system." One such principle, which he called "the principle of homogeneity," prescribed that "scientific explanation within the framework of a certain theory cannot rely on facts lying outside the subject of this theory."[114] The call to build linguistics as a formal logical system was an implicit attack on the pseudo-Marxist ideological considerations that played a prominent role in the dominant Soviet linguistic discourse. Revzin similarly attacked traditional linguists for using imprecise, "subjective" language. Such fundamental linguistic notions as *meaning*, he argued, could be "objectively" defined only through formalization. "Where there are no means of formalization, there is scope for any subjective structure," he maintained. "Only with the presence of clear formal rules for the establishment of identity of meaning is there a guarantee against subjectivism."[115] Revzin also argued that "the existence of more than two hundred different definitions of the term *sentence* makes it impossible to develop [a theory of] syntax on rigorous deductive principles and shows that the definition of basic linguistic units must be approached differently."[116] Revzin particularly attacked definitions (typical of Soviet traditional linguistics) such as "a sentence is a more or less completed thought," and he proposed to formulate a new definition in terms of set theory.

The final arbiter of formal logical consistency of linguistic theories was, of course, the "objective" computer. Mathematicians left no doubt that linguistic theories must pass a computer test. Kolmogorov, in particular, viewed computer modeling as a filter sorting out speculative theories:

> Work in computer translations yields interesting results, in particular for people designing computers and is especially interesting to linguists who, in the process of this work, are forced to specify their formulations of the laws of language. . . . Now it is impossible to use vague phrases and present them as being "laws," something that unfortunately people working in the humanities tend to do.[117]

Structural linguists also believed that only by making their theoretical concepts understood by a computer could they bring linguistics closer to the level of rigor and objectivity exemplified by mathematics. Ivanov's student Igor' Mel'čuk put forward a new "guiding criterion" for introducing linguistic concepts: the possibility of implementing those concepts on a computer. He argued that in this case these concepts would be defined "in a *purely formal* fashion, that is, with unambiguous and logically consistent formulations that do not require any additional information." "*Formal* equals *scientific*," he proclaimed.[118] Having begun his work in the area of machine translation, Mel'čuk later used the formal approach and the conceptual apparatus developed in this field to create an original linguistic theory.

From Machine Translation to Linguistic Theory

Structural linguistics, shunned by the Soviet linguistics establishment, found a place under the institutional umbrella of cybernetics in the field of machine translation. In the second half of the 1950s, Liapunov organized a machine translation group at the Applied Mathematics Division; Ivanov led a similar group at the Institute of Precise Mechanics and Computer Technology; the Institute of Foreign Languages established the Laboratory of Machine Translation, headed by Viktor Rozentsveig; and the Laboratory of Electromodeling, headed by Lev Gutenmakher, created groups of mathematical linguistics and mathematical logic in which both Ivanov and Uspenskii worked part-time. Soviet structural linguists did not merely find a refuge in the field of machine translation; their institutional cooperation with cyberneticians, mathematicians, logicians, computer programmers, and engineers resulted in profound conceptual innovations. Unable to solve practical problems of machine translation because of the acute shortage of computer time, structural linguists focused on theoretical problems of linguistics. They effectively used the conceptual and mathematical apparatus of cybernetics to address some traditional linguistic problems and to create new formal models of language.

In September of 1954 the director of the Institute of Scientific Information, Dmitrii Panov, published in a Soviet mathematics review journal a brief note about the first public demonstration of Russian-English machine translation, which had taken place in January of that year at IBM's Technical Computing Bureau in New York.[119] This report attracted the attention of Soviet authorities, who immediately launched a determined effort "to catch up with the Americans" in this important research area.[120] Recognizing the great potential value of automated translation for intelligence, the KGB set up a special unit to develop a computer system for English-Russian translation. Panov was enrolled as a consultant on this project.[121] Soon after being appointed Deputy Director of the Institute of Precise Mechanics and Computer Technology, he organized a machine translation group there. In late 1955 the group used the BESM computer to test the first version of their English-Russian translation program. Panov professed a pragmatic approach, and placed emphasis on efficient computer algorithms and large computer dictionaries. Instead of trying to do a complete grammatical analysis of the translated text, Izabella Bel'skaia, the leading linguist in the group, developed a set of "linguistic schemes" (ad hoc rules of word-for-word translation). "A study of linguistic structures may be interesting from many different viewpoints," Panov argued, "but from the point of view of translation, such a study seems to be directed at issues of secondary importance and actually distracts from solving main problems."[122]

Liapunov's group in the Applied Mathematics Division took an opposite approach to the problem of machine translation.[123] Liapunov viewed machine translation as a "beyond the clouds" problem: it was impossible to solve completely in practical terms, but it could help generate interesting research projects in computational mathematics and in linguistics. "The development of machine translation," he wrote, "requires a productive use of both linguistic and mathematical-cybernetic methods and often raises substantial questions in both fields."[124] Under Liapunov's guidance, the linguist Igor' Mel'čuk, then an undergraduate at Moscow University, and the mathematician Ol'ga Kulagina, Liapunov's graduate student, designed an algorithm for French-Russian translation of mathematical texts, and the linguist Tat'iana Moloshnaia developed an English-Russian translation algorithm. Liapunov's group devoted much time to the elaboration of general rules of syntactic analysis and synthesis and introduced the concept of "elementary grammatical configurations," which later proved useful in theoretical linguistics.

Liapunov and his colleagues strongly criticized Panov's narrow utilitarian approach and argued that Panov's claims of having achieved machine translation were grossly exaggerated. Panov's hopes for receiving a State Prize were not fulfilled; Moloshnaia wrote later that Panov and Bel'skaia were "publicly exposed, and their results were recognized as false."[125] The conflict between the two groups was not only intellectual but also political. Mel'čuk asserted that Panov was "just an administrator, a loyal Party member," not than a scientist.[126] While Panov was collaborating with the KGB, Mel'čuk's nonconformist political activities were attracting professional attention of the same organization. He was banned from entering the premises of the Institute of Foreign Languages (which trained translators for the KGB), and he had to use a nearby café to meet with linguists working at that institute's Laboratory of Machine Translation.[127] As several leading Soviet structural linguists faced political troubles, their use of machine translation as a cover for structural linguistics research became all the more urgent. In late 1958 Party activists at Moscow University attacked Ivanov for maintaining close links with Roman Jakobson and with the novelist Boris Pasternak. Ivanov's superiors at the Philology Faculty charged that "Ivanov had declared his disagreement with the judgment of the Soviet public and Party activists concerning the anti-Soviet novel *Doctor Zhivago* by Pasternak," and that he had arranged a meeting between Pasternak and Jakobson, whom they labeled "a traitor to his motherland." Ivanov's references to Jakobson's work were regarded as open propaganda for an alien ideology:

> Ivanov by all means supports and popularizes Jakobson's works at international conferences and in the Soviet press. Such personal contacts with and apologetic attitude toward the ideas, conceptions, and the persona of Jakobson, an enemy of Marxism, are incompatible with the dignity of a Soviet patriot scholar.[128]

Intellectual marginality and political nonconformity of structural linguists were closely intertwined. As an innovative researcher and a political emigrant, Jakobson posed a challenge both to the dominant trend in Soviet linguistics and to the ideological dogmas expounded by Soviet science administrators. Ivanov's disagreement with dominant scientific views sowed political discord; conversely, political complications engendered professional marginalization. In December of 1958 Ivanov was fired from Moscow University and lost his position as Deputy Editor-in-Chief of *Voprosy iazykoznaniia* [*Problems of Linguistics*]. Mel'čuk and several other linguists protested Ivanov's dismissal and were forced to leave the university.[129] Unable to find a job in any linguistics institution, Ivanov eventually was hired to lead the machine translation group at the Institute of Precise Mechanics and Computer Technology.

Knowing that the authorities would be more supportive of computer systems with practical outcome than of purely theoretical innovations, structural linguists began to make claims that formal methods in linguistics would pave the road to machine translation. Ivanov later admitted that the discourse of "cybernetic linguistics" often served tactical purposes:

> I cannot say that we intentionally deceived anyone, but it is now impossible to overlook the fact that in those past discussions the practical utility of new methods was if not strongly exaggerated then at least strongly emphasized. Society oriented itself toward pragmatic tasks, and the authorities were willing to allow anything that advanced those tasks. Everybody knew the rules of the game. And we yielded to [the spirit of] the time.[130]

The authorities indeed showed great interest in machine translation, but the bulk of their support went to the special research unit set up by the KGB, whose work remained classified through the 1960s.[131] In academic institutions, the situation with machine translation in the Soviet Union resembled a popular Soviet-era joke: "First learn how to swim, and then we'll fill the swimming pool with water." Liapunov's group at the Applied Mathematics Division, for example, could use only 5 minutes of computer time per week, and translating one sentence on the STRELA computer took about 3 minutes.[132] The position of Ivanov's group at the Institute of Computer Technology was even worse. In the late 1950s, all the researchers at that institute were allowed to use only 5 hours of computer time per week at the Computation Center of the Academy of Sciences. Because of the shortage of computer time, the machine translation group, which was considered of secondary importance within the institute, barely had any access to computers.[133] Another leading specialist in machine translation, Isaak Revzin of the Institute of Foreign Languages, one of the co-authors of *The Fundamentals of General and Machine Translation*, saw a computer—from a distance—only once in his lifetime.[134] By the mid 1960s, Soviet structural linguists proposed "to view machine translation at the current stage as a *theoretical* rather than practical problem."[135]

Structural linguists, who were interested in theoretical linguistics much more than in machine translation in the first place, used this lack of access to working computers to shift the emphasis from machine translation programs to general linguistic models. Soviet linguists argued that machine translation could serve as an experimental base for their theories:

> Machine translation and, generally, automatic analysis and synthesis of texts acquire special significance for linguistics: they provide experimental confirmation of linguistic statements and data. Previously, linguistics included only experimental phonetics, now one can watch the emergence of experimental morphology, experimental syntax, and—what is particularly important and promising—experimental semantics.[136]

However, when structural linguists spoke of "experiments" they usually meant only the theoretical possibility of constructing a computer algorithm, rather than actual computer runs. Obtaining scarce computer time for testing linguistic theories was usually out of the question. Soviet research on machine translation was more of a thought experiment in which the implications of imaginary computer modeling were explored. Machine translation studies often provided models and metaphors for theoretical linguistics, rather than new experimental data.

In cybernetic linguistics, fundamental and applied research switched their traditional roles: machine translation became a vehicle for theoretical linguistics. "Applied linguistics" now applied itself to solving theoretical problems. Referring to machine translation, Ivanov wrote: "This area of applied linguistics so far has been applying itself to linguistics proper by fostering its transformation into an exact science and by providing criteria for testing and selecting models of language."[137]

While being transformed into an "exact science," structural linguistics departed further and further from traditional linguistics. At the 1958 conference on machine translation in Moscow, the Leningrad linguist M. I. Steblin-Kamenskii argued that the attempts to formalize language for the purposes of machine translation would demonstrate that "the same linguistic fact can be described in different ways, depending on definitions; and therefore all linguistic dogmas should be reconsidered"; in particular, he called for a comprehensive critique of "all traditional grammatical concepts such as *sentence*, *parts of the sentence*, and *parts of speech*."[138]

Igor' Mel'čuk, who despite his low administrative status was regarded by colleagues as an "informal leader" of Soviet structural linguistics, led an attack on traditional concepts of linguistics.[139] In particular, he criticized such common terms as *a stable word combination* and *an idiom* as vague. Instead, Mel'čuk proposed a quantitative measure of the stability of word combinations: only those word combinations whose degree of stability exceeded a certain threshold of probability would qualify as "stable." Similarly, he suggested a quantitative measure of "idiomaticity" that would reflect the rarity of the meaning of each word in an idiom. Unlike the "vague" traditional concept of the idiom, this new definition worked well for machine translation:

> This definition . . . makes it possible to construct translation dictionaries automatically. In order to do that, a computer must store parallel texts in two languages and rules for establishing correspondences between elements of these texts. Guided by this definition, the machine would be able to distinguish free combinations from idioms and to create lists of the latter.[140]

Mel'čuk deliberately based his definitions on procedures that in principle could be performed automatically by a computer. In his view, language operated by rules similar to computer algorithms: "Language . . . is a mechanism (that is, a system of rules) that transforms a given meaning into a text and also extracts meaning from a given text."[141] Therefore, if a linguistic theory was to be precise, it had to be rigorous enough to be translated into a set of computer algorithms. Mel'čuk proposed to "describe language not formally, but rigorously, so that a mathematician working together with you could then formalize [this description] independently."[142] Mel'čuk and his collaborator Alexander Zholkovsky put forward the goal of creating a working logical machine that would imitate the human use of language:

> It seems natural to consider the central task of linguistics to be *the creation of a working model of language,* a logical device which, operating on a purely automatic basis, would be capable of imitating human speech activity. This device should be thought of as a system of data and rules, which comprise, so to speak, the grammar or the "handbook" of language, its "working" description, which in principle can be implemented in a computer program. . . . The speaker has a certain meaning in mind and constructs a corresponding text, while the listener receives a certain text and extracts meaning from it. Language here functions as a mechanism in the full meaning of the word, namely, as a device for the transformation, "meaning—text—meaning."[143]

In the mid 1960s, Mel'čuk and Zholkovsky began working on "Meaning—Text," a formal model of linguistic competence based on the principles of machine translation.[144] Initially, they viewed this model as the prototype for an actual English-Russian translation program. They suggested a special "basic" semantic language to express the meaning of the original text. In their view, machine translation would involve three steps: "a transition from English to Basic English (independent meaning-oriented translation); a transition from Basic English to Basic Russian (translation proper); and a transition from Basic Russian to the idiomatic Russian (independent meaning-oriented synthesis)."[145] Lacking access to a computer, Mel'čuk and Zholkovsky were unable to implement the "Meaning—Text" model as a machine translation program. Instead, they began to view this model in a more theoretical light: as a model for linguistic competence in general.[146] They realized that a transition from text to meaning occurs not only in the translation from one language to another but also in the production and understanding of texts in the same language. Mel'čuk and Zholkovsky interpreted formal rules of morphological, syntactic, and semantic analysis and synthesis not just as elements of a machine translation program, but as components of a new linguistic theory.

The "Meaning—Text" model/theory postulated a special "semantic language" that expressed the meaning of a given text. The basic alphabet of this language consisted of elementary semantic units, or "atoms of meaning." Mel'čuk and Zholkovsky defined a set of formal rules of semantic analysis that expressed the meaning of a given text in an ensemble of alternative "semantic representations," reflecting possible ambiguities in the text. Similarly, formal rules of semantic synthesis translated a given semantic representation into a set of synonymous texts. Mel'čuk and Zholkovsky also developed a set of "semantic axioms," or "universal laws of reality," such as "Any action entails the undesirable loss of part of the actor's resources" or "People usually want more than they are entitled to."[147] This "semantic language" thus functioned as a formal axiomatic system. In Mel'čuk's view, this language could be compared to Leibnitz's *Lingua mentalis*, a universal language of thought.[148]

The "Meaning—Text" model implemented an original method of expressing the same meaning in different ways by using not only lexical synonyms but also other linguistic tools of synonymy—an idea originally developed by Zholkovsky and his colleagues in machine translation research.[149] Zholkovsky and Mel'čuk elaborated a procedure of "multiple" synthesis that combined lexical and syntactic variations and produced a large number of synonymous variants of translation (ideally, all possible ones) and then "filtered out" those that were unacceptable. The procedures of analysis and synthesis of natural-language texts, developed initially within the framework of machine translation, thus became incorporated into linguistic theory. Curiously, both meanings of the word *model* were present here: what began as an attempt to build a working model (a prototype) of a machine translation program later became a tool for understanding language, then was seen as the only objective representation of linguistic theory, and eventually played the role of theory itself—a model (an imitation or representation) of human communication.

Ideas and concepts of cybernetics, especially information theory, played an important role in the formation of the "Meaning—Text" model. At first, Zholkovsky and Mel'čuk could not find a rigorous definition for the most crucial concept in their model, the concept of meaning, and wrote that "meaning should perhaps be considered an indefinable concept."[150] Through Roman Jakobson, however, Soviet linguists were introduced to Claude Shannon's definition of information as "that which is invariant under all reversible encoding or translating operations"—in other words, as "the equivalence class of all such translations."[151] Like Warren Weaver, who had extended Shannon's study of information to the analysis of meaning, Mel'čuk turned Shannon's definition of information into a definition of meaning. Mel'čuk defined it as "an invariant of all synonymous transformations, that is, what is common to all equivalent texts."[152] Furthermore, he explicitly stated that the notion of meaning in the "Meaning—Text" model played the same role that the notion of information played in the cybernetic model of communication. Combining elements of Shannon's "general communication system" and Jakobson's "six constituent factors of verbal communication," Mel'čuk formulated a general cybernetic scheme of verbal communication, and he defined language as "a system of tools for the transfer of information."[153] Mel'čuk then established parallels between three main elements of this general cybernetic scheme and those of the "Meaning—Text" model:

(1) information which is to be received and comprehended; in our model, it is represented by *meanings*;
(2) physical signals which carry this information; in our model, they are represented by *texts*; and
(3) code, that is, the correspondence between information and signals; in our model, it is represented by *the correspondence between meanings and texts*.[154]

INFORMATION

SIGNAL

SPEAKER -- LISTENER

COMMUNICATION CHANNEL

CODE

Figure 5.8
The general cybernetic scheme of verbal communication. Adapted from Mel'čuk, *Opyt postroeniia lingvisticheskikh modelei "Smysl—Tekst."*

MEANING

TEXT

SPEAKER -- LISTENER

COMMUNICATION CHANNEL

MEANING—TEXT CORRESPONDENCE

Figure 5.9
The "Meaning—Text" working model of linguistic competence. Adapted from Mel'čuk, *Opyt postroeniia lingvisticheskikh modelei "Smysl—Tekst."*

Linguistics occupied a prominent place both in Liapunov's grand design for the "cybernetization" of Soviet science and in the structure of the Academy Council on Cybernetics. At its inception, the Academy Council included a linguistics section, chaired by Ivanov. Under the umbrella of cybernetic linguistics, this section provided a safe haven for various approaches to the study of language, including descriptive linguistics (usually called "structural linguistics" in the United States), transformational-generative grammar, and Jakobson's phonology. In short, cybernetic linguistics effectively encompassed all the trends in modern linguistics that did not bear the mark of approval by the Soviet linguistics establishment.

Crucial support for the institutionalization of structural linguistics in the Soviet Union came from the Academy Council's chairman, Aksel' Berg. In May of 1960, with Berg's active participation, the presidium of the Soviet Academy of Sciences adopted a resolution "On the Development of Structural and Mathematical Methods in the Study of Language."[155] The resolution called for the organization of structural linguistics sectors in various academic institutions, the launching of the journal *Strukturnaia i* *matematicheskaia lingvistika* [*Structural and Mathematical Linguistics*], and the founding of the Institute of Semiotics. Soon research groups of structural linguists began to form at various linguistics institutions: the sector of structural and applied linguistics (with a machine translation group) at the Institute of Linguistics, the sector of structural linguistics at the Institute of the Russian Language, the group for the study of language with mathematical methods at the Leningrad branch of the Institute of the Russian Language, the sector of structural typology at the Institute of Slavic Studies (headed by Ivanov), a group at the Institute of Oriental Studies. Moscow University opened a Division of Theoretical and Applied Linguistics within the Philology Faculty (after 1962 the Division of Structural and Applied Linguistics), and soon similar divisions were established at universities in Khar'kov, Kiev, Leningrad, Novosibirsk, Riga, and Tbilisi and at the Institute of Foreign Languages in Moscow.[156]

The strategic alliance between Soviet structural linguistics and cybernetics nearly brought about a merger of the two fields in the early 1960s, when the linguists and the cyberneticians joined forces to lobby for the establishment of a united research institute under the Academy of Sciences. This institute was to provide the material and intellectual resources needed to implement the grand project of the "cybernetization" of Soviet science. The fate of this institute had profound consequences for the future of this project.

The Fate of the Institute of Cybernetics

The establishment of the Academy Council on Cybernetics in April of 1959 only partially solved Soviet cyberneticians' problems: the Council had no funds for research; it only coordinated and disseminated information about cybernetic research done in various academic institutions. Through Liapunov's efforts, the Applied Mathematics Division set up a Department of Cybernetics; by 1960 this department numbered 22 researchers.[157] Liapunov argued that this level of support was utterly insufficient. In November of 1961 he told his colleagues in the division:

> Work in the field of cybernetics in our country is not organized. There is no Institute of Cybernetics in Moscow. . . . Most of the work is done haphazardly and with great shortage of funds. Especially funds for experimental work are lacking. . . . Twenty people for this entire field is a very small number. . . . There is no graduate program in cybernetics. The training of specialists is chaotic. In such conditions, it is very difficult to develop cybernetic research. We need help.[158]

Liapunov argued that the Academy of Sciences should establish a separate Institute of Cybernetics to accommodate all the branches of the cybernetics tree, including computing, "cybernetic biology," mathematical economics, and "cybernetic linguistics." In 1960–61 Liapunov and his colleagues drafted a number of documents outlining the structure of the proposed institute. They argued that the need for such an institute was prompted by the interdisciplinary nature of cybernetics: "Since cybernetics has emerged on the basis of the interaction among different disciplines (mathematics, radioelectronics, logic, biology, linguistics, economics, etc.), it can successfully develop at the present time only in a unified academic body, which would unite representatives of all relevant disciplines."[159]

The Institute of Cybernetics was to unite a large number of cybernetic research groups scattered over various institutions inside and outside the Academy of Sciences: the Department of Cybernetics from the Applied Mathematics Division, the Structural Linguistics Sector from the Institute of the Russian Language, the Structural Linguistics Sector from the Institute of Slavic Studies, the Sector of Structural and Applied Linguistics from the Institute of Linguistics, the machine translation group from the Institute of Precise Mechanics and Computer Technology, a group from the Laboratory of Electrodynamics of the All-Union Institute of Scientific and Technical Information, and several groups from military research institutes.[160] By Soviet standards, the proposed Institute of Cybernetics was of medium size. Liapunov wrote that it "should not be too large; even with all positions filled, there should be no more than 300–350 full-time researchers."[161] Liapunov and his colleague Igor' Poletaev proposed for the institute an unusual administrative structure that would include—besides the conventional "triangle" of a director, an executive director, and an Academic Council—a Council of Project Leaders, which was to play the leading role in directing the affairs of the institute.[162] Liapunov's proposed organizational structure for the institute was as follows:

1. Department of Logic and Cybernetics
a) sector of the theory of control systems;
b) sector of mathematical logic;
c) sector of the theory of programming.

2. Department of Statistics and Cybernetics
a) sector of information theory;
b) sector of the theory of stochastic processes;
c) sector of queuing theory.

3. Department of Semiotics
a) sector of machine translation;
b) sector of mathematical linguistics;
c) sector of informational logical languages;
d) sector of specialized languages of science.

4. Department of Economics and Cybernetics
a) sector of economic control systems;
b) sector of game theory;
c) sector of economic planning.

5. Department of Biology and Cybernetics
a) sector of physiology of the central nervous system and analyzers;
b) sector of biological control systems;
c) sector of self-learning models.

6. Department of Computer Experiments
a) sector of computer operation;
b) sector of computer modeling;
c) sector of computer programming.[163]

The mathematicians Gnedenko, Iablonskii, Khurgin, Markov, and Uspenskii, the linguists Ivanov and Mel'čuk, the geneticist Efroimson, and the computer specialist Kitov were mentioned as candidates for leading research positions at the Institute.

In parallel with cyberneticians' efforts to establish the Institute of Cybernetics, structural linguists lobbied for the creation of an institute of semiotics in Moscow. The linguists proved more successful, and in May of 1960 the presidium of the Soviet Academy of Sciences decided to organize the Institute of Semiotics. The linguists, led by Ivanov, asked the mathematician Andrei Markov Jr. to serve as director, and he agreed. The cyberneticians, led by Liapunov, tried to convince Markov that he should change the name of the institute to "Institute of Semiotics and Cybernetics" and to broaden its research program to include all branches of cybernetics. In June of 1960 leading cyberneticians and structural linguists gathered to discuss this situation. The struggle over the control of the future institute took the form of a lively debate on whether semiotics was part of cybernetics or a separate field. The dispute was resolved by Markov, who announced that semiotics was in fact a part of cybernetics—moreover, its central part—and rejected the name "Institute of Semiotics and Cybernetics" as "not only wrong but also harmful, since it points to the potential possibility of partition."[164] Markov proposed "Institute of Cybernetics," and all sides agreed.

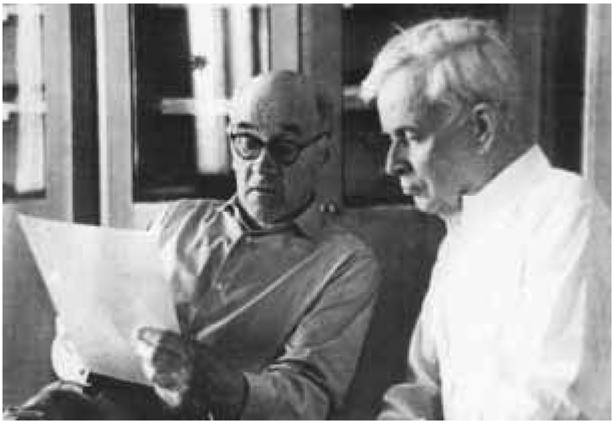

Figure 5.10
Aksel' Berg and Andrei Markov Jr., 1963. From Pospelov and Fet, eds., *Ocherki istorii informatiki v Rossii*.

Figure 5.11
At left: Aleksei Liapunov, Norbert Wiener, and Gleb Frank, Moscow, 1960. Courtesy of Natal'ia Liapunova.

The chairman of the Council on Cybernetics, Aksel' Berg, used his connections at the top of the Party and government hierarchy to draw support for the institutionalization of cybernetic research. In July 1961, during a meeting with the newly elected president of the Academy, Mstislav Keldysh, Berg argued that his council was not equipped to develop cybernetic research on a large scale: "We cannot content ourselves with the existence of a merely consultative organ with no rights, no staff, no money, and no office space."[165] He lobbied for the establishment of a whole network of cybernetic research facilities: "We are talking about creating a group of institutes that would study fundamental scientific problems crucially important for medicine, economics, biology, and industry. Comrades from the State Planning Committee and the Central Committee support this idea."[166]

The bureaucratic machine of the Academy moved cautiously and slowly. Finding a building for the new institute posed a formidable problem. Khrushchev's policy of decentralizing scientific research resulted in a ban on the construction of new buildings for academic institutions in Moscow. When discussing possible locations for the institute, Berg even suggested using the sturdy building of the Butyrskaia Prison—which he knew well, having served time there in the late 1930s.[167] Eventually, in September of 1961, the presidium of the Academy of Sciences adopted a resolution to construct a new building for the Institute of Cybernetics in Noginsk, a small town in the Moscow region, in 1963–1965.[168] This was, however, too little too late. Having lost any hope for the organization of the institute in Moscow any time soon, Liapunov moved to the newly built Akademgorodok in Siberia, where excellent living and working conditions were created for him and his staff.[169] Without Liapunov's driving force, the movement for the organization of the institute soon lost its steam. Neither the Institute of Cybernetics nor the Institute of Semiotics materialized.[170] Instead, the Council on Cybernetics acquired the formal status of an academic institute, but without any expansion of its staff.[171]

The failure of the attempts to establish the Institute of Cybernetics reflected deep-seated disagreement and discontent among Soviet cyberneticians. As Uspenskii has later recalled, "various scientific, semi-scientific, academic, and semi-academic groups [had] very different views on how to organize an Institute of Cybernetics."[172] Liapunov and Markov, in particular, strongly disagreed over the research agenda of the future institute.[173]

Multiple interpretations of cybernetics were pulling the Soviet cybernetics community apart. Cybernetics was stretched over too many fields and served too many agendas. The original intention to conceptualize cybernetics as a maximally broad field backfired: reaching a consensus over the meaning of cybernetics became problematic.

"What Is Cybernetics?"

Cyberneticians, who aspired to make other scientific disciplines more objective by "cybernetizing" them, could hardly agree, however, on exactly what *cybernetics* meant. As the cybernetics movement grew wider, the definition of *cybernetics* was becoming broader and broader.

The initial 1955 article by Liapunov, Sobolev, and Kitov described cybernetics as a unity of three theories: information theory, the theory of computers as self-organizing logical processes similar to human thinking, and the theory of automatic control systems (including the study of the nervous system).[174] Three years later, Liapunov and Sobolev published another article, in which they spoke of four definitions, rather than parts, of cybernetics:

1. Cybernetics is a science studying control systems and control processes with mathematical methods.
2. Cybernetics is a science studying the processes of governance and control in machines, living organisms, and human society.
3. Cybernetics is a science studying the processes of transmission, processing, and storing information.
4. Cybernetics is a science studying the methods of creating, transforming, and explicating the structure of algorithms that describe actual control processes.[175]

In 1959 Liapunov and Sobolev published a revised version of this article in which they eliminated the second definition (which, incidentally, was the closest to Norbert Wiener's original conception of cybernetics as a science of "control and communication in the animal and the machine"). Liapunov and Sobolev believed that the notions of *control*, *information*, and *algorithm* were so deeply interconnected that they even could be defined through one another. For example, they defined *information* as "the totality of messages that can be communicated in processes of control." In their view, any "control process" involved some "information processing" governed by certain algorithms. The discursive boundaries between control theory, information theory, and computing vanished altogether when Liapunov and Sobolev defined "the algorithm of information processing in a given control process" as "the totality of all elementary acts of information processing and all the logical conditions to be checked."[176]

For Liapunov, any intellectual activity was a form of "control process" governed by some "control algorithm," which could in principle be implemented on a computer. Cybernetics, in his view, was to study precisely such (computer) algorithms of control. At the October 1956 session of the Soviet Academy of Sciences, he gave the following definition of cybernetics:

> Any intellectual process, when its algorithm is revealed, no longer requires intellect and can be mechanized. The main condition for the transfer of a certain control process to a machine is the creation of an algorithm that describes this process in terms of elementary logical operations or operations that could be reduced to them and executed by a machine. . . . The science concerned with the methods of construction and analysis of the structure of algorithms . . . and the description of algorithms is a new branch of knowledge known as "cybernetics."[177]

At the same session, Andrei Kolmogorov criticized both Wiener's version of cybernetics (for eclecticism) and Liapunov's version (for reducing cybernetics to computer programming):

> In our country certain comrades, in particular A. A. Liapunov, feel that . . . a theory [that] unites mathematical questions related to the functioning of computers and controlling devices working discretely in time . . . should be called cybernetics. However, the word cybernetics was introduced by N. Wiener, who gave it a much wider significance. Cybernetics according to Wiener . . . includes an important part of the theory of stability for systems of differential equations, classical control theory, the theory of random processes with their extrapolation and filtration, the theory of information, game theory with applications to operations research, the technical aspects of logic algebra, the theory of programming and many other topics. It is easy to understand that as a mathematical discipline cybernetics in Wiener's understanding lacks unity, and it is difficult to imagine productive work in training a specialist, say a postgraduate student, in cybernetics in this sense. If A. A. Liapunov can formulate the program of development of a narrower and more unified discipline, then in my opinion it would be better not to call it cybernetics.[178]

Soon Kolmogorov put forward his own version of cybernetics. In April of 1957, at a session of the Moscow Mathematical Society, he presented a paper titled "What Is Cybernetics?"[179] This paper was a draft of his upcoming article in the *Great Soviet Encyclopedia*, in which he defined cybernetics as a research field studying "the methods of receiving, storing, processing, and using information in machines, living organisms, and their associations." Building on his own work on information theory, Kolmogorov placed the notion of information in the center of his version of cybernetics, and defined other major concepts of cybernetics through this notion. In particular, he defined *communication* as "the receiving, storing, and transmitting of information," and he introduced two varieties of control: *guidance* and *regulation*. Guidance was defined as "the processing of received information into control signals," and regulation as "the processing of received information into regulatory signals."[180] In the same volume of the *Great Soviet Encyclopedia*, Kolmogorov also published an article on information, which he introduced as the main concept of cybernetics.[181]

Even though the appearance of Kolmogorov's article on cybernetics effectively legitimized this field, it did not settle the question of the meaning of the term. Andrei Markov Jr. publicly ridiculed Kolmogorov's definitions, insisting that they produced a vicious circle: cybernetics was defined through information, while information was defined through cybernetics. Kolmogorov responded by redefining information as "an operator that changes the distribution of probabilities in a given set of events." Markov dismissed this definition too, and mockingly described how "a given computer would receive a given operator, which changes the distribution of its probabilities, and store this operator on its magnetic drum."[182] The word *information* was used differently in information theory (where the *amount of information* characterized the diversity of messages produced by the *information source*) and in computing (where the term *information* stood informally for any kind of data processed by a computer). The unification of information theory and computing under the rubric of cybernetics created a new discursive field, in which the two meanings of the term *information* functioned together; this produced the confusion pointed out by Markov.

In 1964, contributing to the ongoing debate, Markov published his own article under the title "What Is Cybernetics?" In it he proposed to define cybernetics as a "general science of causal networks."[183] Markov also redefined information as probabilistic causality: A contains information about B if A causes B with a certain probability. Using his preferred mathematical apparatus, Markov uniformly described such diverse phenomena as the nervous system, a species, a biological population, and an individual organism as probabilistic causal networks.

The mathematician Sergei Iablonskii, a former student of Liapunov's, proposed yet another version of cybernetics. Specializing in algebraic logic, Iablonskii attempted to translate cyberspeak into the language of that logical theory. In a 1963 article, Liapunov and Iablonskii defined any "control system" as a finite automaton characterized by its state ("memory," or "information"), its structure ("the scheme"), its "coordinates" (self-knowledge, or feedback capacity), and its "function" (its actions, which could change its state, structure, coordinates, or the function itself).[184]

Each of the Soviet mathematicians most actively involved in the cybernetics movement—Kolmogorov, Markov, Liapunov, and Iablonskii—attempted to make his own favorite mathematical theory the foundation of cybernetics. Kolmogorov promoted information theory; Markov advanced causal networks; Iablonskii advocated algebraic logic. Liapunov's mathematical specialty, descriptive set theory, also left a strong imprint on his version of the "cybernetization" of science. In every field, he first delineated elementary concepts and their classes, then defined operations on these classes, then determined the basic theoretical postulates (the "axioms"), and subsequently applied the standard methodology of set theory.[185]

Soviet authors realized that their versions of cybernetics differed significantly from the original Western conceptions of this field. They viewed the works of Western cyberneticians as a point of departure, rather than as a theoretical canon. The physiologist Nikolai Bernshtein frankly admitted that his own vision of cybernetics went far beyond specific Western incarnations of this field:

> We shall treat the term *cybernetics* not as the doctrine of Wiener, Shannon, and Ashby, but rather as a new branch of science, engendered in our times under the pressure of necessity, whose study is associated with the general problems of control theory, information theory, and communications theory.[186]

Liapunov and Iablonskii also acknowledged that their concept of *control system* was much broader than Wiener's notion of *control*; they even admitted that "among control systems may appear certain objects in which there is no control in the usual sense."[187] In Wiener's interpretation, control was always directed at improving organization. For Liapunov and Iablonskii, control was a much looser concept; it included all types of causation, not only those that led to a higher degree of organization. In Liapunov's view, one object exercised control over another if "a signal from the first object [caused] changes in the behavior of the second object."[188] According to Iablonskii, the broad category of control systems included "systems that actually perform control (such as neural tissue or [computer] programs), systems that are controlled (computers, economic systems, and so on), and systems that are not related to control in the usual sense (such as chemical molecules or chess games)."[189] This broad interpretation of control was acceptable, Iablonskii argued, because it was "convenient."

Soviet authors often criticized one another for their free play with cybernetic concepts. Liapunov's heavy emphasis on control upset Kolmogorov, who apparently favored another cybernetic concept: information. In a 1964 private letter, Kolmogorov wrote sarcastically: "Liapunov and others believe that all organic evolution is 'controlled' by someone from above. If the organic life on earth suddenly disappears, this perhaps would be an expression of the highest 'control.'"[190] It was "illegitimate," argued the mathematician Igor' Poletaev, to apply the terms *control* and *information* indiscriminately to describe all interactions between parts of a given system, and to call all systems with such interactions "control systems." He maintained that both Liapunov and Markov described physical systems with terms that related only to their (mathematical) models. "From our perspective," wrote Poletaev, "this 'terminological inaccuracy' is unacceptable, for its leads (and has led already) to a departure from Wiener's original vision of cybernetics toward an inappropriate and irrational expansion of its subject."[191] "As the result," he warned, "the specificity of the cybernetic subject matter completely disappears, and cybernetics turns into an 'all-encompassing science of sciences,' which is against its true nature."[192]

Soviet cyberneticians were concerned about the lack of unity in the cybernetic discourse, but they were not able to reach a consensus. Liapunov and Sobolev, in particular, admitted that the multiple definitions of cybernetics gave the impression of a "great discord dominating in cybernetics." They suggested that readers pay attention not to the "formal definitions" but to the "concrete content" of research, so that cybernetics would be seen as a "sufficiently unified scientific discipline."[193] Aksel' Berg also acknowledged that there was no universally accepted definition of cybernetics, but insisted that scientists could do just fine without it. Definitions were "the concern of philosophers," he wrote. "In mathematics and logic, it would suffice if we are able to operate in practice with such concepts as life, time, space, information, and many others, and also to measure some of them and to express them in quantitative terms."[194]

Cybernetics, which was supposed to bring formal rigor and exact reasoning to the sciences, was itself conspicuously lacking a formal definition. All cyberneticians agreed that it was useful to have a common interdisciplinary language; they strongly differed, however, on the meaning of cybernetic terms. Different members of the cybernetics community had very different intuitive notions about the content and the boundaries of cybernetics. The entire cybernetic project of a deep reformation of science ran into an internal difficulty.

This Page Intentionally Left Blank

6

Cybernetics in the Service of Communism

[The proposed unified automated control system for the national economy] would make it possible to fully implement the main economic advantages of communism—centralized control and the planned economy. This would ensure full harmony and a match between the political and economic structures of the communist state and the technical means for controlling the national economy.

—Aleksei Liapunov and Anatolii Kitov, "Cybernetics in Technology and in the Economy" (1961)[1]

Soviet Cybernetics as a "Science of Government"

Soviet cybernetics began gradually to fashion itself as a universal methodological guide for science, technology, economics, and even politics. This evolution of cybernetic discourse was reflected in the notable change in the translation of Wiener's favorite term, *control*. In the early 1950s, Soviet critics of cybernetics translated the word *control* in the title of Wiener's magnum opus, *Cybernetics, or Control and Communication in the Animal and the Machine*, literally as *kontrol'*.[2] In contrast, Soviet advocates of cybernetics chose a different Russian word—*upravlenie*—to render the term *control* in the 1958 Russian translation of Wiener's book.[3] Both *kontrol'* and *upravlenie* can be translated as *control*, but they differ in their nuances. The word *kontrol'* refers to the processes of checking and examination, while *upravlenie* has such meanings as management, administration, direction, and government.[4] Russians speak of *kontrol'* when the controller is bound by a preset goal and only monitors the controlled process but does not direct it (e.g., quality control). *Upravlenie*, on the other hand, applies to administrative decision making and often involves setting new policies (e.g., managing a factory or governing a state).[5] Speaking at Moscow University in November of 1961, Engineer Admiral Aksel' Berg, the chairman of the Academy Council on Cybernetics, frankly admitted: "Many people don't seem to like the word *cybernetics*. I don't like it either, but we haven't yet come up with a better one. It would be better to use a Russian word. That's why we often speak of a new *science of government* [*upravlenie*]."[6]

From its very inception, the Academy Council on Cybernetics interpreted the term *cybernetics* very broadly. Berg argued that cybernetic methods of control were applicable to all "dynamic systems," including technological processes, living organisms, and human collectives. He believed that even the most complex technological and social systems were amenable to cybernetic control:

> There are no unknowable phenomena, only unknown ones; likewise, there are no uncontrollable processes, only those in which the complexity of the task is not yet matched by the methods and means for its solution. Cybernetics broadens the range of controllable processes; this is its essence and its major merit.[7]

The main task of Soviet cybernetics, Berg announced, was "the development of methods and the application of tools for controlling the entire national economy, individual technological processes, and various forms of economic activity to ensure the optimal regime of government [*upravlenie*]."[8]

To underscore this broad interpretation of cybernetic control, the editor of the Russian edition of *Cybernetics*, the mathematician Gelii Povarov, added an extensive footnote in which he traced the genealogy of cybernetics past Wiener to the French physicist André-Marie Ampère.[9] Ampère had introduced the word *cybernétique* in the 1830s to denote the science of government in his classification of sciences, and listed *cybernétique* among the political sciences.[10] In his initial report on the prospects of cybernetic research to the presidium of the Soviet Academy of Sciences in April of 1959, Berg referred to Ampère in the very first sentence. Berg mentioned Wiener only later in his talk, emphasizing that the latter "reused" the term *cybernetics*. Berg also often linked main ideas of cybernetics to the ideological legacy of Lenin, who in the 1920s had called on Bolsheviks to learn "the fundamentals of the science of government [*upravlenie*]."[11] Soviet cybernetics proved to be a very political science indeed.

Berg's personality, which paradoxically combined the gallantry of the Russian nobility, the iron fist of the Soviet military, the sensibility of a former prisoner of the Gulag, and a naive faith in the bright Communist future, made a decisive impact on the activities of the Cybernetics Council, which he chaired. Berg acted as a great spokesman for progress and packed his

Figure 6.1
Aksel' Berg lecturing. Courtesy of Russian Academy of Sciences Archive, Moscow.

publications with such expressions as "new scientific and technological opportunities," "new science," "progressive scientists," "the reevaluation of values," "the rejection of obsolete doctrines," and "the path of progress." Cybernetics, a new, "young" science, embodied for him this progressive spirit.

Berg pushed cybernetics forward with the thrust of an icebreaker. He had no pity for his worst enemies—"backward people," "skeptics, dogmatists, and conservatives."[12] During one of his frequent TV appearances, Berg passionately exclaimed that the conservatives who interfere with scientific progress must be "publicly executed by a firing squad in Red Square."[13] In his informal remarks at a 1967 session of his Council, Berg expressed his agenda in unequivocal military terms:

> When the computer enters our home . . . there will be no need to call a doctor; the machine will tell you what to do. Students will not have to go some place and listen to hideous lectures of old pensioners, who know nothing; programs will be optimized and you will have connection with a machine, which will come to your home, as water and light did. . . . If someone does not believe it, let him commit suicide. This is the future, and we will fight for it, and we will weed out anybody who would interfere.[14]

Propagandizing in favor of cybernetic ideas became of the main activities of Berg's Council. In 1961 the council sponsored "Cybernetics in Our Lives" (a series of twelve 20-minute programs on Moscow radio), "Faster than Thought" (a series of broadcasts on the Moscow TV channel), and more than 200 lectures before various "collectives of workers, clerks, students, engineers, scientists, managers, and the personnel of the Central Committee of the Communist Party."[15]

Berg mobilized his council to publish a volume, appropriately titled *Kibernetiku—na sluzhbu kommunizmu* [*Cybernetics—in the Service of Communism*],[16] in time for the opening of the Twenty-Second Congress of the Communist Party in 1961.[17] His efforts paid off when a new Party Program adopted at this Congress mentioned cybernetics among the sciences called upon to play a crucial role in the creation of the material and technical basis of communism. The published draft of the new program stated that it was "necessary to organize the wide use of cybernetics"; the final version adopted at the congress more vigorously asserted that cybernetics and electronic computers and control systems would "be widely applied" in production, research, planning, and management.[18] The popular press began to call computers "machines of communism."[19]

The word *cybernetics* began to acquire favorable ideological connotations. The Cybernetics Council adopted *Cybernetics—in the Service of Communism* as the title of its regular proceedings. Berg used any occasion, including a session of the Biological Sciences Division of the Academy, to emphasize publicly the great political significance of cybernetics:

> However unusual this may sound to some conservatives who do not wish to comprehend elementary truths, we will be building communism on the basis of the most broad use of electronic machines, capable of processing enormous amounts of technological, economic, and biological information in the shortest time. These machines, aptly called "cybernetic machines," . . . will solve the problem of *continuous optimal planning and control.*[20]

In the 1960s, "optimal planning and control" became a motto of the cybernetic movement. Soviet cyberneticians assumed that the main problem of the Soviet economy lay in the inefficient mechanisms of data collection, information processing, and control, and offered a solution based on mathematical modeling and computer-aided decision making. They believed that computers produced a politically neutral, "optimal" solution, and hoped that cybernetics would create an opportunity to reform Soviet planning and management practices without cardinal political change. One memoirist aptly called such cyberneticians *considents*, meaning half-consenting dissidents.[21] Soviet cyberneticians were looking for a technological solution to an inherently political problem; by its own nature, however, their project was doomed to play a political role.

The "Dialectical Materialization" of Cybernetics

Cyberneticians initially chose cyberspeak as a value-free, "objective" language, hoping to limit their discussions with the authorities to technical terms. Instead, cyberspeak itself became politicized. In the post-Stalin period, Soviet philosophers lost their position as ideological watchdogs and judges of scientific controversies, and cyberneticians played a prominent role in the efforts to discredit dogmatic philosophy. The old order was turned upside down: philosophers could no longer reprimand scientists; quite the opposite, cybernetics now claimed to be a guide to solving philosophical problems. As the historian Alexander Vucinich has put it, "the new orientation demanded a shift in emphasis from the interpretation of modern science in the light of dialectical materialism to the interpretation of dialectical materialism in the light of modern science."[22] Philosophers quickly reorganized: they did not challenge the validity of cybernetic research, but instead adapted philosophical discourse to cybernetic innovations. Well trained in newspeak techniques, some philosophers now adopted cyberspeak as a new ideological language.

While leading Soviet cyberneticians viewed official philosophy as an enemy, Aksel' Berg, more skilled in the Soviet bureaucratic etiquette, preferred to work out a compromise. When he said that scientists did not have to give a precise definition of cybernetics because it was "the concern of philosophers," he actually meant it. In January of 1962, at a session of the presidium of the Council on Cybernetics, Berg proposed to add a philosophical section to the council. "Philosophy permeates everything," he said, "and a philosophical section must be considered most important." Andrei Markov Jr. immediately remarked that such a section would be superfluous: "If philosophy permeates everything, then everyone must be a philosopher. If we create a separate section, philosophical issues would be isolated from the rest." The mathematician Anatolii Dorodnitsyn, director of the Computation Center of the Academy of Sciences, realized the political advantages of having a team of loyal philosophers on staff, and disagreed with Markov: "Mathematics also permeates everything, but the mathematical section exists. Therefore, a philosophical section must exist too." The linguist Sebast'ian Shaumian suggested an elegant linguistic solution: to call the section "methodological" rather than "philosophical." The presidium eventually agreed to organize a "commission," rather than a section, on "methodological foundations of cybernetics," under the condition that non-philosophers would also be included. Berg assured the critics that "philosophy, like other sciences, must obey the order and not be anarchistic."[23] Soon the commission quietly transformed itself into the Philosophical Section.[24]

The Philosophical Section had a clear mission: to reconcile cybernetics with dialectical materialism by adapting dialectical materialism to cybernetics. Philosophers loyal to cybernetics duly accomplished this task. First, they managed to incorporate the concept of information into the canonical list of categories of dialectical materialism. Wiener's formula, "information is information, not matter or energy,"[25] which had provoked so much philosophical criticism during the anti-cybernetics campaign, was reinterpreted in a dialectical light. "Information is not identical with matter," one philosopher wrote, "although it would be wrong to consider information a non-material entity."[26] Another author argued that, while negative entropy expressed the orderliness of matter, information referred to the orderliness of one of the attributes of matter: reflection. The inherent connection between negative entropy and information, therefore, confirmed the unity of matter, a basic postulate of dialectical materialism.[27] This author identified noise with "disordered reflection" and emphasized the "dialectical rotation of information and noise."[28]

Philosophers loyal to cybernetics not only reconciled cybernetics with dialectical materialism but also effectively worked out a strategic alliance between the two. Cybernetics no longer posed a challenge to dialectical materialism; it no longer served as a stick with which Liapunov and Sobolev tried to chase philosophers out of the domain of science. Cybernetics was tamed and domesticated; a former rebel turned into a respectable discipline fully compatible with the principles of dialectical materialism.

To propagandize the new alliance between cybernetics and dialectical materialism, the Philosophical Section organized a conference on philosophical problems of cybernetics in June of 1962 in Moscow, attended by more than 1,000 philosophers, psychologists, mathematicians, physicists, biologists, engineers, computer specialists, and educators from 30 cities. Philosophers employed by the Council on Cybernetics told the participants that cybernetics was "the most important element of the contemporary natural scientific foundation of dialectical materialism."[29] An application of the same cybernetic models to qualitatively different phenomena was fully justified by the principle of the material unity of the world, they argued. By attributing an "objective character" to the notion of purpose, "cybernetics delivered a sharp blow to idealistic teleology."[30] Cybernetics enriched the treasury of dialectical principles of Soviet philosophy by "the principle of unity of the discrete and continuous approaches" and "the principle of unity of the deterministic and probabilistic approaches."[31] Not a word of philosophical criticism of cybernetics was raised at the conference.

Soviet authors quickly turned cybernetics—formerly labeled a "handmaid of religion"—into a handmaid of atheism. One journalist argued that "if man can design machines which in a simplified form simulate the workings of the brain, then mental activity must be a natural, material process, and therefore no soul, no supernatural element allegedly put into man by god can really exist."[32] Another author defined God as "information isolated from any signals and existing by itself"; since information could not be carried without signals, he reasoned, the existence of God was also impossible.[33] Books with titles like *Cybernetics is Anti-Religion* and *Information Theory and Religion* appeared.[34]

Cybernetics occupied a prominent place in the fundamental five-volume *Philosophical Encyclopedia*, published in 1960–1970. The philosopher Aleksandr Spirkin, head of the Philosophical Section, served as Deputy Editor-in-Chief of the encyclopedia, and he secured the publication of an 11-page article on cybernetics. (The article on mathematics was only 6 pages long.) The encyclopedia also included as separate entries such terms as *control systems*, *information theory*, *coding*, *algorithm*, *isomorphism*, and *homomorphism*, thus turning them into philosophical categories.

The encyclopedia article on cybernetics fully reflected the new domination of cybernetic discourse over the old philosophical clichés. The first draft, written by Ernest Kolman, was mildly critical of cybernetic claims, but after a discussion at the Philosophical Section of the Council on Cybernetics it was forcefully rejected. Kolman emphasized the "qualitative differences" between humans and machines, and argued that cybernetic devices did not have consciousness and therefore could not think.

Cybernetics supporters brushed such formulations aside as too limiting. "Why such a sharp boundary between man and machine?" asked one critic. Another remarked: "It is said [in the draft] that cybernetic devices have no consciousness. But so far we have not really figured out what is consciousness." Discussants argued that only cybernetics, not philosophy, could answer the crucial question about the difference between man and machine:

> The existence of an essential boundary between man and machine so far has not been proved; this would be a major discovery, not something self-evident. . . . What is stated now as the quantitative differences between machines (of today) and the human brain may be overruled by the development of science.[35]

Cyberneticians now did not have to submit their articles to philosophers for approval; quite the opposite, it was cyberneticians who corrected philosophers' writings. The Philosophical Section threw Kolman's manuscript out and appointed a group of loyal pro-cybernetics philosophers employed by the council to write a new article for the encyclopedia. The new version, which was eventually published, placed no philosophical limits on cybernetics; it stated that "the question of the possibility of creating automata of a new type that . . . would have the abilities of reduplication, adaptation to the environment, self-improvement, and creativity . . . is currently open to debate."[36]

Soviet cybernetics gradually assumed the same guiding methodological role that had previously been claimed by official philosophy. In this role, cybernetics employed the same discursive techniques that made Soviet ideological discourse so flexible, adaptable, and virtually universal. Like the language of dialectical materialism, the language of Soviet cybernetics possessed an ambiguous terminology and some flexible rules of reasoning, which offered great freedom to the speaker. Both newspeak and cyberspeak imposed limitations on how to speak but left much room for what could be said, as long as it was said in the right way. Like official philosophy before it, cybernetics now boasted its complete objectivity, political significance, and universal applicability.

Cybernetics in Fashion

Soviet cybernetics became fully legitimized, officially recognized, and almost canonized, but this proved to be a Pyrrhic victory. Cybernetics acquired its place under the sun at the expense of losing its rebellious spirit and turning into a fashionable trend. As cybernetic concepts acquired the degree of generality characteristic of ultra-flexible categories of dialectical materialism, cyberspeak began closely to resemble newspeak. Cybernetics laboratories and institutes mushroomed throughout the Soviet Union, and many career-minded scientists began using *cybernetics* as a buzzword. It was now trendy to call oneself a cybernetician, and suddenly the cybernetics movement became very crowded.

When former opponents of cybernetics realized that they could not defeat it, they decided to join it. Orthodox Pavlovians, for example, had initially claimed that cybernetics contradicted Pavlov's teaching and was therefore a pseudo-science, but now they completely embraced cybernetics and argued, with equal zeal, that reflex theory fully agreed with cybernetics, and that Pavlov himself was all but the founding father of cybernetics. To support this claim, Iurii Frolov, one of Pavlov's orthodox disciples, unearthed a forgotten 1936 article by the mathematician N. A. Romanov, who had proposed a probabilistic model of Pavlovian reflexes.[37] "Of course, this does not mean that cybernetics was 'discovered' in Pavlov's laboratory," admitted Frolov, "but this testifies to the fact that the mathematician Romanov . . . was the first to point out the closest connection between the teaching of Pavlov and the theory of probabilities as the core of modern cybernetics."[38]

The excessively broad interpretation of cybernetics was facilitated by Aksel' Berg's efforts to expand the authority of his Cybernetics Council indefinitely. The results of the council's 1966 nationwide overview of cybernetic research are reproduced here in table 6.1.[39]

As the scope of the Cybernetics Council widened to incorporate an ever-growing number of institutions and research fields, the council had to reduce its role from the substantive coordination of research to the simple collection and dissemination of information about ongoing projects. This superficial activity produced little effect. In December of 1967, at a celebratory

Table 6.1

	1962	1963	1964–65	1966	1967–1970
Projects	170	231	374	428	500
Institutions	29	61	96	133	150
Agencies	14	19	22	27	50

session of the Cybernetics Council dedicated to the fiftieth anniversary of the Bolshevik Revolution, Berg made a frank admission later struck from the record: "In practical terms, we are lagging behind, and nothing useful is being done, but we do our work and will keep doing it. I hope we will succeed!"[40]

The expansion of cybernetics came at the expense of meaningful synthesis. Berg was willing to bring under the cybernetics umbrella any study that involved computing or used the terms *control*, *information*, or *communication*, and he stretched the concept of cybernetics almost without limit. In July of 1962 Berg proposed to reorganize the council to cover practically all of Soviet science. He illustrated his idea with a formidable table: eight rows represented basic fields (philosophy, psychology, mathematics, information theory, computing, reliability theory, physics, and chemistry), and twelve columns covered cybernetic applications (in biology, medicine, neuroscience, physiology, the management of the national economy, economics, linguistics, law, the energy sector, manufacturing, chemical industry, and transportation).[41] The total number of cells in the table amounted to 96, and the council, according to Berg's plan, was to coordinate research nationwide in all 96 areas.

Cybernetics specialists began to realize that Berg's enthusiasm was going too far. Anatolii Dorodnitsyn stated bluntly that it was "impossible to implement everything proposed." The mathematician Boris Gnedenko, Deputy Chairman of the council, agreed: "We cannot do everything; we do not have sufficient forces. It is necessary to delineate the most important part, that is, the one that actually relates to cybernetics, and to appoint a commission of 10–15 members to hear all serious proposals."[42] A few days after this meeting, Sergei Iablonskii wrote to Liapunov:

> On the Council. [The situation] has become very difficult. There are almost no results from the Council. Berg only demands paperwork and strives for the expansion of the Council. . . . Berg demands plans, personal assignment of tasks, and so on, while we insist on formulating key problems and focusing all efforts on their solution. Such issues, in our opinion, must be as follows: the organization of the Institute of Mathematical Problems of Cybernetics, the strengthening and expansion of *Problems of Cybernetics,* and the support of certain research groups. Positions on these issues sharply differ. Berg told us to draft plans and all sorts of explanations, and then he would see. In the meantime, all available vacancies [at the Council] already disappeared (probably, wasted on some nonsense). We did not receive a single position for research![43]

Without Berg's support, Liapunov, editor of the series *Problems of Cybernetics*, could not obtain the permission to transform this publication into a regular journal. Liapunov began to distance himself from the fussy activity of the council. Like Karl Marx, who had been so disgusted with the vulgarization of his teaching that he refused to call himself a Marxist, Liapunov, the accepted "father of Soviet cybernetics," declined to write for the series *Cybernetics—in the Service of Communism*.

The Soviet cybernetics movement spread well beyond Liapunov's original design and took on a life of its own. After his move from Moscow to Akademgorodok in Siberia in 1961, Liapunov lost his influence over the activities of the Cybernetics Council and numerous research groups that rallied under the banner of cybernetics. As one memoirist put it, after Liapunov's departure "the center that had unified cybernetics disappeared, and cybernetics naturally split into numerous branches." Liapunov, he continued, "had been the living embodiment of cybernetics as a unified movement, and nobody else could play this role."[44] Various groups began to pull Soviet cybernetics in various directions in accordance with their particular research agendas and political goals. The more people jumped on

Figure 6.2
Mikhail Lavrent'ev (left) and Aleksei Liapunov with a stack of *Problems of Cybernetics* volumes. Courtesy of Natal'ia Liapunova.

the cybernetics bandwagon, the less certain it was in which direction this wagon was going.

From "Military Cybernetics" to "Economic Cybernetics"

Numerous contributors to the 1961 collection *Cybernetics—in the Service of Communism* enthusiastically called for the introduction of computers and cybernetic methods into industry, biology, neurophysiology, medicine, linguistics, chemistry, power systems, transportation control, and the judicial process. Most important, they claimed that cybernetics could help automate and optimize the management of the national economy. Anatolii Kitov, in particular, wrote that "the national economy as a whole may be regarded as a complex cybernetic system, which incorporates an enormous number of various interconnected control loops with various levels of subordination." He argued that only the application of cybernetic methods—mathematical modeling and computer simulation—could place economics on a solid scientific foundation: "Computer modeling makes it possible to forecast economic processes and to conduct mathematical experiments in economics. Thereby economics turns into an exact experimental science."[45] In January of 1959 Kitov sent the Party Central Committee a copy of his 1958 book *Electronic Computing Machines* along with a proposal to create an automated control system for the national economy that would be based on a unified network of state computation centers. The authorities appointed a commission, headed by Berg, and soon the Central Committee and the Council of Ministers issued a joint decree on the improvement of production and introduction of computers into the economy.[46]

Berg, Kitov, and Liapunov summarized the essence of cyberneticians' aspirations to reform the Soviet economy in a 1960 joint article in the Party journal *Kommunist*. To increase the productivity and quality of management, they argued, managerial tasks must be automated. Citing positive Western experience, they suggested using computer technology and cybernetic methods of information processing on a scale much greater than in the West:

> The dominant trend in the area of management is the transition toward complex automation of all types of information processing with the help of electronic computer technology, aimed at creating "a fully automated managerial office." . . . In contrast to capitalist countries, where different companies create individual auto-

mated control systems for themselves, in the conditions of socialism it is quite possible to organize a unified complex automated system to control the national economy. It is obvious that the effect from such automation would be much greater than from the automation of control of individual enterprises.[47]

The authors argued that the automation of management would greatly improve the efficiency and productivity of Soviet industry. They wrote, for example, that the use of computers would help reduce procurement planning time from 3–4 months to 3 days, cut the management apparatus by half, and decrease the cost of procurement procedures by a factor of 5. To support the outlined automated control system for the national economy, the authors proposed to build a unified territorial network of information computation centers with centralized control. These centers were to be linked to individual institutions and industrial enterprises, whose computational needs they would serve. The entire network was to provide means for automatic collection of economic data, planning, distribution of resources, banking, and control of transportation.

The initiative in applying computers to the automation of economic management came not from chief Soviet economists and planners, who remained largely conservative, but from cyberneticians working for the military. As a result, the initial visions of automated economic management were heavily influenced by the concept of automated military control and command. Liapunov explicitly compared economic decision making to military command:

In one important type of control algorithms, the purpose of an algorithm is the struggle against another control system or another algorithm. . . . [Such problems] emerge before the reflexologist, who plans experiments, which may be regarded as a struggle against the nervous system of the experimental animal. The same issues arise before the economist, who plans the work of an enterprise or a branch of industry, and calculates the most rational way of overcoming external problems. Finally, the commander on a battlefield faces similar problems.[48]

Soviet specialists in "military cybernetics" viewed weapons systems, including both machines and the people who operated them, as cybernetic systems:

Any combat item (a tank, an aircraft, or a ship) can be seen as a typical cybernetic system with all its characteristic elements. The controlling organs or devices in such systems are the commanders and their control points, while the controlled objects are the weapons and the technical elements of the combat item. . . . With respect to troop control, the controlling organ is the commander and his staff, while the controlled objects are subordinate military units or combat items.[49]

Military cyberneticians proposed that computers and cybernetic algorithms of optimal control be applied to control not only automated weapons but also military units. Computation Center 1 of the Ministry of Defense began working on the principles of automated troop control.[50] Cyberneticians argued that a "decision reached with the help of an electronic computer is more objective, for it is based not on a subjective opinion of a single person (the commander) and his intuition, but on collective experience, on those operational-tactical views that are generally adopted in a given military area."[51]

Military cyberneticians were eager to apply the same concept of cybernetic control both to military command and to economic management. In 1959–1961 a group of military experts, which included Anatolii Kitov (then Deputy Director of Computation Center 1), Nikolai Buslenko, Lazar' Liusternik, and Igor' Poletaev, advocated the creation of a dual-use nationwide network of computation centers for both military and civilian applications. These centers were to be placed underground in secret locations and protected against a direct bomb hit. Then the centers were to be linked by hidden lines of communication to civilian stations in big cities, so that their powerful computers could process economic data in the time left after making all calculations for the military. The Ministry of Defense, however, rejected their proposal outright. The military leaders decided that combining military and civilian functions was "inexpedient." Kitov later wrote that, in his view, the real reason behind the negative reaction to their proposal was that "people in power were concerned that, as a result of the introduction of computer technology, many of them could prove redundant."[52]

Soviet cyberneticians' proposals for a cybernetic reform of managerial practices posed a direct challenge to the existing power hierarchies. Cybernetic analysis of information flows and managerial procedures exposed serious flaws in Soviet economic management, and cyberneticians believed that the introduction of cybernetic methods would help reform the obsolete managerial practices. For example, citing studies of data-collection procedures in Soviet industry, Liapunov argued that the contemporary managerial practices were clearly inadequate:

> Certain data required for expedient control are, in fact, neglected, while much information, which is collected with great effort, has no function to fulfill, for this information does not affect decision making in production management. . . . As a result, many agencies and information channels duplicate one another and make

no real impact on production. A detailed mathematical modeling of production control would help find out which links in a control system are not necessary, and perhaps would help arrive at a more rational system of control in general.[53]

Cyberneticians explicitly contrasted the promised efficiency of cybernetic control with the ineptitude of the cumbersome Soviet bureaucracy. In December of 1957 the leaders of the Soviet Academy of Sciences wrote to the presidium of the Party Central Committee:

The use of computers for statistics and planning must have an absolutely exceptional significance in terms of its efficiency. In most cases, such a use would make it possible to increase the speed of decision making by hundreds of times and to avoid errors that are currently produced by the unwieldy bureaucratic apparatus involved in these activities.[54]

Cyberneticians' proposals challenged not only the existing administrative hierarchies in the government bureaucracy, but also infringed on the authority of the Communist Party. The officially recognized ideological supervisory function of the Party could hardly be formalized in cybernetic control algorithms. Critics of "military cybernetics" were quick to point out that computers lacked ideological vision:

Outside cybernetics' field of vision, there appear such cardinal questions about controlling military forces as the relationship between objective and subjective factors, the distribution of functions among control organs, the role of ideological and psychological factors, and so on.[55]

The Chief Political Directorate of the Army reportedly played an active role in blocking the cyberneticians' proposal to create a dual-use nationwide network of computation centers. As Poletaev recalled, one official had asked him with disdain: "Where is the leading role of the Party in your [computing] machine?"[56]

The military leaders quickly suppressed the cybernetic trend in the military ranks. In 1961 Computation Center 1 was transformed into Central Scientific Research Institute 27, and its functions were limited to the introduction of computers to automate individual military activities, instead of building automated troop-control systems.[57] The young reformers Kitov and Poletaev were forced to leave the army; Kitov was also expelled (temporarily) from the Communist Party. They transferred their cybernetic aspirations to other fields: Poletaev began working on mathematical models in biology, and Kitov was hired by Viktor Glushkov, director of the Institute of Cybernetics in Kiev, to supervise the introduction of automated management systems based on the "method of network planning and control" (the Soviet version of the Western Program Evaluation and Review Technique, or PERT) in the defense industry. Glushkov's team later tried the same method in civilian enterprises.[58]

Inspired by "military cybernetics," early proposals for cybernetic reforms in the economy were filled with military imagery. Glushkov argued that without computers "scientifically based control of the economy [would be] just as impossible as, say, military operations without the use of weapons."[59] Viktor Belkin, an economist from the Institute of Electronic Control Machines of the State Planning Committee drew an illuminating comparison between controlling the national economy and launching a missile. Before the advent of computers, he wrote, the calculation of a missile's trajectory took too much time, and this had precluded the construction of guided missiles. Now computers could calculate missiles' trajectories faster than the missiles could fly, and this made it possible to guide missiles in real time. Similarly, Belkin argued, the introduction of computers in economics would provide the opportunity to calculate and correct economic plans in real time.[60]

In the 1960s, Soviet military cyberneticians' aspirations to create a computerized "guidance system" for the national economy led to some far-reaching efforts by mathematical economists and "economic cyberneticians" to develop systems of "optimal planning" for the Soviet economy. As with "military cybernetics," proposals advanced by Soviet "economic cyberneticians" provoked some serious controversy.

"Optimal Decision Making on a National Scale": Aspirations and Constraints

Under the umbrella of cybernetics, a new trend in Soviet economic thought—"economic cybernetics"—emerged. The participants of Liapunov's open seminar on cybernetics at Moscow University often discussed the prospects for applying mathematical methods in economics. In May of 1957, for example, the Leningrad mathematician Leonid Kantorovich, the Soviet pioneer of linear programming, presented a paper on mathematical methods in economic planning. Ten days later, two cyberneticians spoke about a proposed "high-speed computer for economic analysis."[61] The Academy Council on Cybernetics set up an Economics

Section, regularly published papers on mathematical economics in *Cybernetics—in the Service of Communism*, and sponsored several conferences on that topic. In 1958 only a handful of Soviet economists were interested in mathematical models of planning and management; 3 years later, more than 40 institutions were conducting research on mathematical economics.[62] In 1967 the Council on Cybernetics coordinated cybernetics research in some 500 institutions, and half of them were engaged in applying cybernetic methods to economics.[63] "Economic cyberneticians" advanced their ideas in constant struggle with the conservative elite among Soviet economists.

Soviet economists were among the first in the world to apply mathematical methods to nationwide economic planning. In 1926 the State Planning Committee (Gosplan) calculated a balance sheet of the Soviet economy for 1923–24. The idea of balanced economic development did not fit into Stalin's plans for the forced collectivization of agriculture. In a 1929 speech he dismissed the Gosplan calculations as "a numbers game," and many of the "players" soon disappeared in purges.[64] While writing his pioneering 1939 work on linear programming, *Mathematical Methods of Organizing*

Figure 6.3
Leonid Kantorovich (left) receiving the Nobel Prize in economics from King Carl XVI Gustav of Sweden in 1975. From Pospelov and Fet, eds., *Ocherki istorii informatiki v Rossii.*

and Planning Production, Kantorovich used the terms *organizing* and *planning* instead of *economics*, since at that time mathematical economics as it had been developed in the West was labeled "anti-Marxist" by Soviet critics; the purpose of using mathematics in economics, they argued, was to defend capitalism.[65] The publication of Kantorovich's second book on mathematical economics, *Economic Calculation of the Best Use of Resources*, written in the early 1940s, had to wait for more than 15 years. By the early 1950s, political economists thoroughly dominated Soviet economic studies; mathematical methods had been pushed to the margins of the discipline.

With the political "thaw" and the growth of economic problems, however, Soviet leaders began contemplating an economic reform and permitted an open discussion of its possible directions. A group of prominent economists and mathematicians led by Kantorovich, Vasilii Nemchinov, and Viktor Novozhilov challenged the authority of political economists and proposed to use mathematical methods and computer technology for efficient planning, price regulation, and processing of economic information. Conceptualizing the Soviet economy in cybernetic terms as a giant control system, they aspired to transform the entire Soviet economic system into an optimally functioning one. This formidable task faced serious technical and political difficulties.[66]

Soviet economic cyberneticians interpreted economic management as a form of cybernetic control [*upravlenie*] and brought Western studies on "management science" under the umbrella of cybernetics. Cybernetics was viewed as a guide to the automation of production control and to the automated management of the national economy. In July of 1962 the Academy of Sciences dispatched a group of experts to the United States and England to learn about the latest methods of industrial automation. Upon their return, members of the delegation wrote a confidential report, in which they argued that cybernetics ("management science") would provide new methods for industrial automation and economic management:

> Management science in the United States incorporates the main ideas of automated control of machinery, the principle of feedback, and the methods of application of this principle. The main purpose of this science is the elaboration of methods of optimal planning and industrial management. The delegation believes that now is the time to utilize in a serious way the achievements of management science under the conditions of planned economy in our country in order to place solid scientific principles in the foundation of economic management and production control with the help of operations research methods.[67]

Proposals for cybernetic ("rational," "objective," "scientific") control of the economy had the ear of Party authorities. At a Central Committee plenum in November of 1962, Khrushchev called on his Party comrades to adopt Western "rational" managerial techniques. In the conditions of the planned economy, he argued, these techniques would be even easier to implement than under capitalism.[68] Also in November of 1962, Aleksei Kosygin, then Deputy Chairman of the Soviet Council of Ministers, met with two leading mathematicians—Mstislav Keldysh and Viktor Glushkov—to discuss the prospects for using cybernetic methods to control the economy. Keldysh and Glushkov proposed to optimize economic decision making on a national scale by creating a nationwide automated system, based on a unified state network of computation centers, for economic planning and management. Soon the Council of Ministers appointed Glushkov to head a commission charged with preparing a detailed proposal.[69]

Glushkov originally envisioned a system that would monitor all labor, production, and retailing. He even proposed to eliminate money from the economy, evoking the Marxist utopian vision of a communist society.

Figure 6.4
Viktor Glushkov and Aksel' Berg at the Institute of Cybernetics in Kiev. Courtesy of Russian Academy of Sciences Archive, Moscow.

Perhaps Glushkov hoped that this idea would appeal to Khrushchev, who in 1961 had announced the Party's goal of building communism in the Soviet Union by 1980. Keldysh, who was much more experienced in top-level bureaucratic maneuvers, reportedly advised Glushkov to drop this radical idea, explaining that it might "arouse unnecessary emotions." Glushkov then excluded this section from his main proposal and submitted it to the Party Central Committee separately. If ideology was to play any significant role in the Soviet top-level decision making, this was its best chance. Glushkov's proposal to eliminate money, however, received neither support nor a formal response from the Party authorities.[70]

In a more acceptable form, economic cyberneticians' proposals gradually made their way through the maze of Soviet government agencies. Eventually, in 1963, the Party Central Committee and the Council of Ministers adopted a joint decree titled On Improving the Supervision of Work on the Introduction of Computer Technology and Automated Management Systems into the National Economy. Several major government agencies involved in the management of the national economy established specialized institutions to study problems of automated management: the Academy of Sciences set up the Central Economic Mathematical Institute (hereafter CEMI),[71] the State Planning Committee organized the Main Computation Center, and the Central Statistical Administration created the Scientific Research Institute for Design of Computation Centers and Economic Information Systems. To coordinate all work in this area, the government set up the Chief Administration for the Introduction of Computer Technology into the National Economy.

CEMI, organized with the active support of Berg's Council on Cybernetics, became the hotbed of economic cybernetics. The director of CEMI, Academician Nikolai Fedorenko, also became the chairman of the Scientific Council on Optimal Planning and Management of the National Economy. CEMI put forward an ambitious program of optimal economic planning on a national scale, based on the cybernetic methods of controlling large-scale complex systems. In 1964 CEMI's research agenda was formulated as follows:

(1) Elaboration of a theory of optimal planning and management, and the construction of a general mathematical model of the national economy;
(2) Development of a unified system of economic information;
(3) Development of a unified state network of computation centers;

(4) Development of mathematical methods for the general model;
(5) Creation of concrete planning and management systems based on mathematical methods and computer technology; and
(6) Elaboration of standards and algorithms for planning and management.[72]

CEMI cooperated closely with Glushkov's Institute of Cybernetics. In 1964 Glushkov and Fedorenko published a joint proposal for a unified system of optimal planning and management on the basis of a three-tier unified nationwide network of computation centers. The proposed network included tens of thousands of local computation centers to collect "primary information," 30–50 mid-level computation centers in major cities, and one top-level center controlling the entire network and serving the government. The structure of the computer network was made flexible enough to provide independence from possible reorganizations of planning and management agencies, which were quite frequent in those days. In the existing economic system, the central planning organs collected primary economic information from individual enterprises by means of four relatively independent parallel channels: the planning system, the material-technical supply system, the statistical system, and the financial system. Glushkov and Fedorenko proposed to replace this scheme with one in which all economic data would be collected only once, stored in data centers, and then made available to all the agencies involved. By this restructuring of economic information flows, the authors hoped to reduce the number of reports submitted by an individual enterprise by a factor of 20–30.[73] Glushkov and Fedorenko promised that the proposed unified system of optimal planning and management would provide "optimal decision making on a national scale" by processing "the entire body of primary economic information as a whole."[74]

Economic cyberneticians quickly realized that it was impossible to centralize all economic decision making in Moscow: the mathematical optimization of a large-scale system was simply not feasible. CEMI researchers estimated that complete optimization of the Soviet economy required solving a gargantuan system of equations with 50 million variables and 5 million constraints. They admitted that even a computer performing 1 million operations per second, which was much faster than any available Soviet computers, would require one month to solve a system a billionth as large.[75] Besides, economic cyberneticians realized that there were some serious conceptual difficulties: linear programming was suited for the problem of resource distribution, but it did not work well for prospective planning, there were different views on what constituted an economic optimum, and it was difficult to agree on a single criterion for optimization.[76] In 1967 Fedorenko unequivocally stated that "the full formalization of the functioning of an economic system and the creation of a fully automated centralized system of planning and management of the economy is unwarranted."[77]

Economic cyberneticians envisioned a hybrid planning system that would provide for some decentralization of decision making while preserving the backbone of the Soviet economic system: the national plan. While some Western observers described their projects in very simplistic terms as attempts at "perfect computation," Soviet mathematical economists developed a truly sophisticated concept of optimal planning based on the use of the market mechanism through "indirect centralization."

"Optimal Planning": A Vehicle of Economic Reform or an Obstacle to It?

The idea of indirect centralization, introduced by Viktor Novozhilov, was based on a mathematical theorem stating that the equilibrium point in a many-person non-coalition game would be an optimum.[78] Applying the results of game theory to the Soviet economy, economic cyberneticians argued that the central government did not need to impose specific output quotas on individual enterprises; instead, it could set "optimal" prices and investment efficiency norms, then allow individual enterprises to make their own decisions. If the criteria of economic performance were properly formulated, the independent activity of individual enterprises should lead to the fulfillment of the national plan. In contrast to the accepted view, economic cyberneticians argued that the ideal of "optimal planning" could be achieved by a radical decentralization of economic decision making and a regulated use of the market mechanism:

> The finding of an optimum may take place in a decentralized way, i.e. the equilibrium point, or optimum, can be found as a result of an exchange of information between economic organs, each of which independently solves the problem of optimization guided by its own individual (local) criterion of optimality. . . . In this way, it is possible to use the market mechanism for organizing the process of the decentralized working out of the optimal plan.[79]

Economic cyberneticians viewed optimal planning as a way to introduce an economic incentive system and to let the economy self-regulate within some general constraints imposed by the national plan. They sought a rational, "scientific" justification for the ideologically dubious notion of *khozraschet* (a profit-based system of economic incentives for individual enterprises). Describing the Soviet economy in quintessential cybernetic terms, Novozhilov argued that the market mechanism was equivalent to the feedback principle:

> By now it is already widely known that cybernetics justifies *khozraschet* as the compensator of randomness in a planned economy. A socialist economy is a very complicated system subject to the activity of a multiplicity of random factors and not lending itself to description in full detail. The control of such systems is possible only on the condition that there exists a self-regulator with feedback, which can speedily compensate for the action of random factors and bring the system back to the target state or the target path of development. A self-regulator with feedback keeps an eye on the values of various variables (e.g. the profitability of production) and acts on the system in such a way as to prevent an excessive deviation of these variables from their normative values. In a socialist economy the market mechanism [tovarno-denezhnye otnosheniia] is such a regulatory mechanism. . . . The basic proportions of the development and the chief controlling normatives must be established by the national economic plan. The detailing, correction and fulfillment of the plan must be regulated by *khozraschet*.[80]

In the absence of real market mechanisms in the socialist economy, computer modeling of these mechanisms was to provide quasi-market stimuli for individual enterprises. In the early 1960s, the Institute of Electronic Control Machines in Moscow, led by the computer designer Isaak Bruk, built the specialized M-5 computer for economic applications and began calculating "optimal" prices for a comprehensive price reform.[81] Kantorovich also proposed a mathematical model for calculating shadow prices on the basis of "objectively determined valuations," which reflected the relative scarcity of products, thus taking into account the relationship between supply and demand.

Economic cyberneticians strongly emphasized their reliance on "objective" computation and "objective" valuations. Contrasting their approach with the traditional discourse of Soviet political economy, which was loaded with ideological formulas borrowed from the Marxist theory of value, they strongly asserted the discursive autonomy of economic cybernetics from political economy: "[The Marxist concept of] value and objective valuations are two completely different and incommensurable things. Value is a category of political economy and objective valuations are an algorithmic formula for the calculation of equilibrium prices in an optimal plan."[82]

Sharply criticizing orthodox economists at a 1959 session of the Academy of Sciences, Kantorovich argued that the impossibility to translate their theories into cyberspeak made the shallowness of these theories self-evident:

> The computer cannot digest some of our economists' scholarly products. Their long talks and articles on economic topics, which people listened to and read and thought they understood, proved impossible to use. Any attempt to give them a logical-mathematical, algorithmic form in order to enter them into a computer failed. It turned out that, after removing everything that was said "in general" (sometimes there was substance, but it related to sociology or politics, not to economics per se), and after pouring out all the "water," there was either nothing left, or just one big question mark, the formulation of an unsolved problem.[83]

The idea of optimal planning not only challenged some dogmas of political economy but also threatened to upset the existing hierarchy of power in the economic sphere. An introduction of optimal planning would have undermined the monopoly of the State Planning Committee on top-level economic decisions; the government bureaucracy would have had to yield some of its power to mathematical economists. Central economic agencies therefore attempted to limit cybernetic experiments to low-level management: they suggested that economic cyberneticians start with the optimization of local planning, and then gradually move up to a nationwide system. Cyberneticians objected, arguing that it was impossible to achieve local optimization without reforming economic mechanisms on a national scale.[84]

Despite the Soviet leadership's general encouragement of their approach, economic cyberneticians faced a stern opposition from the same government agencies that were supposed to help in the implementation of optimal planning projects. Instead of directly opposing the cyberneticians' reforms, these agencies began to scale down and delay these projects. As it made its way through various government committees and commissions, Glushkov's original proposal for a nationwide automated control system for the economy was completely emasculated. The economic reform part disappeared; only a nationwide network of computation centers was preserved, and its functions were reduced significantly. In November of 1964 the Soviet government transferred the responsibility for "finalizing" Glushkov's proposal to the Central Statistical Administration. That agency quickly replaced Glushkov's concept of creating a unified network of computation centers with the idea of installing some computers at the existing statistical data-collecting stations. The State Planning Committee opposed this idea, fearing that the narrow specialization of computation centers would give an advantage to a rival agency, and insisted on rewriting the proposal to include some planning functions. As the two powerful government agencies struggled, trying to adapt Glushkov's project to their own ends, the prospects for building a unified system of optimal planning and management on the basis of a nationwide network of computation centers quietly withered away.[85] In 1968 Kitov wrote in a personal letter to Liapunov:

> The top leadership realizes the importance of [the introduction of computers into the national economy] but takes no effective measures in support of such work, while responsible officials from the ministries and other government agencies . . . display no interest in the automation of management or the optimization of planning. The problem is apparently rooted not in their personalities, but in their positions [in the bureaucratic hierarchy] and in the overall traditions, which change very slowly.[86]

Kantorovich's attempts to optimize the production of pipes by rearranging the existing network of producers and suppliers ran into a stone wall. One sympathetic ministry official told him: "The Ministry of Metallurgy decides what to produce, and the Ministry of Supplies decides how to distribute it. Neither will yield its powers to anyone. To implement your plan, one must change the entire management system." One factory manager offered a similar explanation: "I cannot reallocate portions of the salary fund; it comes with the state order. This fund is greater for narrow pipes. If you rearrange the orders, this will upset the stability of this fund. To accept your plan, the entire system of management has to be reformed."[87]

While industrial managers and government bureaucrats resisted the computerization of economic planning and management because it could upset the existing power structures, liberal economic reformers opposed Glushkov's proposal because they feared it would further centralize the control of the economy and suppress local initiative. Liberal economists insisted on the radical decentralization of economic planning and management and on the introduction of actual market mechanisms in the Soviet economy. If central planning organs and individual enterprises could arbitrarily manipulate various economic criteria, they argued, computers could only produce "distorted results, though with great speed."[88]

Liberal economists warned that Glushkov's project would divert resources urgently needed for economic reform and merely conserve the obsolete forms of centralized economic management. The economist

Gavriil Popov, who would later play a prominent political role in Mikhail Gorbachev's *perestroika*, severely criticized Glushkov's proposal in a 1970 book:

> [The construction of] the pyramids of Egypt was one of the reasons why that fertile ancient country turned into a desert. If one vigorously implements a meaningless economic decision, it ruins the economy. According to the blueprint of a unified state network of computation centers, these centers would spread over this country like those pyramids, designed by talented mathematicians and able engineers with the participation of unqualified economists.[89]

Glushkov indeed admitted that his project for a nationwide network of computation centers would cost more that the space program and the atomic project put together.[90]

Several pilot projects aimed at the development of small-scale computerized systems for production control and information management at individual factories had little success. "Optimal" control yielded poor results when the technology of production was old and obsolete, as was often the case at Soviet factories. At a metallurgical plant in Dneprodzerzhinsk, the use of computers to control a technological process saved minutes, while hours were wasted because of inefficient technology, faulty sensors, and lack of coordination among the stages of production.[91] Glushkov admitted that any potential profit from management-information systems was also lost because of constant interruptions in supply and the inefficient organization of the industry as a whole.[92] "Optimal planning and control" turned into a pure mathematical abstraction. Elena Markova, a specialist in "chemical cybernetics," has recalled that cyberneticians' suggestion to computerize production control at the Moscow chemical plant was met by plant managers with deep skepticism: "Look, this pipe is leaking, and ammonia leaks out by buckets. What is the point of talking about the optimization of ammonia production? If our machinists were not drunk, the efficiency would have skyrocketed without any computers."[93]

Having limited political options, Soviet cyberneticians tried to work out a mathematical solution to the political problem of reforming the Soviet economy. Many of the leading Soviet cyberneticians involved in economic projects—Berg, Bruk, Glushkov, Kantorovich, Kitov, Liapunov—were not economists but rather engineers or mathematicians. Their vision of optimal economic planning was based on mathematical optimization, but it worked only on paper. While hoping to use mathematical methods and computer modeling to advance their reform program, they did not realize that cybernetics could be employed—perhaps even more effectively—to conserve the existing power structures and administrative hierarchies.

Cybernetics in the Service of the Establishment

After October of 1964, when Khrushchev was ousted and Brezhnev came to power, the drive for reform in the Soviet economy quickly withered away. Soviet cybernetics underwent a parallel change: it transformed from a vehicle of reform into a pillar of the status quo. The Soviet political, economic, and academic establishment successfully appropriated cyberspeak and computer technology to serve its own goals.[94]

Under Brezhnev, Khrushchev's decentralized system of regional economic management was quickly dismantled, and the centralized managerial structure of ministries and state committees was restored. Officials at various industrial branch ministries quickly realized that there were many ways to skin the cybernetic cat without necessarily losing their grip on power. Instead of building a nationwide automated management system that would connect all branches of industry within each region, they proposed to develop information-management systems along industrial branch lines. In March of 1966 the Party Central Committee and the Soviet Council of Ministers adopted a joint decree that made this approach an official policy.[95] It was decided that each ministry would set up a separate automated management system to serve its internal needs. Now the ministries did not have to share information/power with any rival agency; on the contrary, each ministry could use computer technology to strengthen its control over sensitive information.

If computerized management systems were compatible, they could serve to unite different enterprises; if they were incompatible, they would divide enterprises just as effectively. Built without much coordination, branch-based information-management systems proved incompatible with one another and with that of the State Planning Committee, and thus their integration was not possible. By constructing isolated information-management systems, Soviet industrial branch ministries laid a technical foundation for strengthening the centralized control over their subordinate enterprises. "Having different ministries is like having different governments," one contemporary observed.[96]

Instead of facilitating the mechanism of "indirect centralization" envisioned by economic cyberneticians, computer technology was enrolled to strengthen hierarchical structures of centralized control. In 1970 the director of Gosplan's computation center criticized the supporters of the "theory of optimal planning" for their "nihilistic approach" to centralized planning.[97] Gosplan officials effectively used computers to shore up their habitual planning practices rather than to reform them.

With the decline of the idea of a nationwide automated management system, CEMI's mission was significantly reduced. By the end of the 1960s, the nationwide economic management system was not even mentioned in CEMI's plans. CEMI's areas of research were defined as follows:

(1) Elaboration of systems theory for optimal national economic planning;
(2) Development of automated systems for planning and management; and
(3) Analysis of problems of national economic development for the period, 1971–75, and forecasting future economic growth.[98]

Mathematics and computing was now "on tap, not on top" of economic decision making. CEMI had to fit its automated systems into the existing managerial structures, instead of developing a new approach to industrial management. In CEMI's plans, the elaboration of cybernetic algorithms for economic planning and management was replaced with a reference to the then-fashionable "systems theory," which placed emphasis on qualitative rather than quantitative analysis of control mechanisms.

A new impetus for the idea of a nationwide computer network came from the West when the Soviets learned about the development of the ARPANET, the predecessor to the Internet. Glushkov immediately drew the attention of the Soviet leaders to the similarity between this American project and his own 1964 proposal for a unified state network of computation centers. In his memoirs, Glushkov recalled:

> In the late 1960s, the Central Committee and the Council of Ministers received information that Americans had drafted the design of an information network (several information networks, to be precise) as early as 1966, that is, 2 years after us. Unlike us, however, they did not argue but got to work, and in 1969 they already planned to launch the ARPANET network, . . . which linked computers installed in various American cities. Then some concern began to show in our quarters. I came to see [the secretary of the Central Committee] A. P. Kirilenko and handed him a memo that proposed to return to the ideas of my original project. "Write down in detail what has to be done, and we will create a commission," he said. Then I wrote something like this: "The only thing I ask is not to create a commission. Commissions operate on the principle of subtraction of brains, not summation, and they can wreck any project." They created a commission all the same.[99]

Glushkov argued that, unless the processing of economic information was automated, by the mid 1980s nearly the entire adult population of the Soviet Union would be engaged in planning, accounting, and management.[100] To solve this problem, he proposed to build a Statewide Automated Management System (*Obshchegosudarstvennaia avtomatizirovannaia sistema upravleniia*, hereafter OGAS)—a network of regional and branch-based management information systems that would include all levels of control, from the top government level to production-control systems at individual factories. Glushkov believed that the larger was the object controlled by an automated management system, the greater was that system's economic effect.[101] To coordinate the entire project, he proposed to establish a State Committee on the Improvement of Management, a powerful interbranch agency staffed with scientists who would oversee the construction and operation of a nationwide automated management system. Glushkov lobbied hard, trying to win over the support of the Soviet leaders. In his memoirs, comparing his situation with the position of the leaders of the Soviet space program and the atomic project, Glushkov wrote:

> Both Korolev and Kurchatov had a curator among the Politburo members. They could come to him and resolve any issue. Our problem was that we did not have such a person. . . . It was particularly important to have a direct contact with one of the Politburo members, since our task was not only scientific and technical, but also political.[102]

The Soviet leaders also realized that the OGAS project, unlike the space program and the atomic project, had direct political implications, which threatened the established hierarchy of power. The published draft resolution of the Twenty-Fourth Party Congress included the full-scale OGAS project, but shortly before the congress the Politburo decided to scale it down drastically. Instead of creating a powerful State Committee on the Improvement of Management, the Politburo resolved to set up a much more modest agency, the Chief Administration for Computer Technology. The elaboration of mathematical models for the national economy and the implementation of automated management systems were put off, and only the least ambitious, largely technical part of the plan—the construction of a state network of computation centers—survived.[103]

While losing its top-level reformist component, the revised OGAS project acquired a completely different political dimension: it now served to conserve the existing power structures and administrative hierarchies, rather than reform them. Resorting to cyberspeak, one Western observer has ascribed the failure of a nationwide automated management project to "bureaucratic entropy":

> The massive computerization campaign aimed at alleviating bureaucratic entropy was itself mired in bureaucratic entropy. . . . With each enterprise fending for itself, a confusing variety of incompatible programs, each written in a different language but performing similar and related tasks, appeared. Thus, instead of aiding the integration of administration, computerization actually reinforced existing organizational boundaries.[104]

Behind this "entropy," however, one could find quite deliberate efforts by the Soviet bureaucracy to preserve local control of information.

Unlike central economic organs, Soviet military and intelligence agencies quickly realized the opportunities for large-scale information collection and processing that computer technology had opened up. In September of 1968 the Party Central Committee and the Soviet Council of Ministers issued a joint decree, titled On the Improvement of Scientific and Technical Information in the Defense Industry and the Exchange of Information Among Different Branches of the Economy, that instructed the State Committee on Science and Technology to set up a Special Scientific Information Center, equipped with new computers imported from France, to supply scientific and technical information to the Chief Intelligence Administration of the Soviet Armed Forces General Staff, the State Security Committee (the KGB), and other government agencies. The center was created on the basis of the Department of Scientific Institutions of the All-Union Institute of Scientific and Technical Information. In 1963–1968 this department compiled dossiers on 70,000 foreign scientists, engineers, and executives and on 5,000 companies from Western countries. The department produced 284 analytical reports on the leading military industrial and scientific research centers in the United States, England, France, Italy, West Germany, and Japan, and it provided detailed responses to more than 2,000 specific queries from the Chief Intelligence Administration and the KGB. The department distributed its classified publications to 420 addressees, including 35 copies for the Central Committee. With the introduction of computer technology and the organization of the Special Scientific Information Center, it was planned to expand the existing database to keep dossiers on some 500,000 leading foreign scientists, weapons researchers, and company executives, including information on their places of work, their professional activities, their political views, and their visits to the Soviet Union.[105]

While downscaling Glushkov's plans for a nationwide automated management system, Party leaders displayed interest in introducing computer technology to rationalize the functioning of the Party apparatus. One Party ideologue argued that the proposed nationwide network of computation centers for economic management "can be used—and it should be used—for gathering, processing and analyzing information on socio-political and ideological processes as well, for the purpose of optimal management [of society]."[106] In September of 1969 CEMI submitted to the Central Committee a proposal to create an Information Computation Center for the Central Committee apparatus. CEMI proposed to design an "information system" that would combine several functions:

1) communication system: fast and reliable collection, distribution, and transmission of information;
2) computation system: various computation tasks, including the calculation and comparative assessment of different alternatives;
3) integrated data-processing system: complex automated processing, preparation, and distribution of documents;

Figure 6.5
Party leaders Leonid Brezhnev and Mikhail Suslov viewing the latest model of the PROMIN' computer at an exhibition in Moscow. Courtesy of Virtual European Museum of Computer Science and Technology.

4) information-management system: accumulation and organization of data on various topics, processing of information requests, and preparation of briefs;
5) information-gathering system: collection of new information in monitored fields; processing and supply of this information;
6) directive-organization system: systematic organization of directives and instructions for various agencies and officials for specific situations, and transmission of these directives at a set time;
7) optimization system: evaluation of various alternatives in accordance with set directives, and selection of the optimal variant through mathematical analysis and programming;
8) experience-accumulation system: systematic organization of decisions and methods of decision-making, and analysis of the best decision-making methods in specific situations; and
9) controlling system: monitoring of all decisions and persons responsible for their implementation, and informing the superiors of the fulfillment (or non-fulfillment) of their decisions at all levels.[107]

According to the proposal, the Central Committee Information Computation Center was to keep dossiers on Party, government, and industrial cadres; to process and analyze petitions from ordinary citizens; to process information on population dynamics and on moral, cultural, and political values; to accumulate information on foreign social movements and political organizations; to provide computer simulations of various international crisis situations and select optimal solutions; to analyze the effectiveness of various propaganda and counter-propaganda methods in the media; and to recommend how better to organize ideological work.

Soviet bureaucrats, in a way, learned the lessons of cybernetics better than did some overenthusiastic cybernetic reformers. Instead of creating a nationwide network, Soviet computerization efforts resulted in a patchwork of incompatible information-management and production-control systems. Instead of facilitating the decentralization of power through computer simulation of market mechanisms, computer technology now served to strengthen centralized control within each ministry. The growing power of ministries quickly reduced the autonomy of individual enterprises to a minimum, and economic reforms were effectively buried. The idea to reform the government with the help of a nationwide automated management system was abandoned. Information gathered at secret information-processing facilities, usually designated as "special computation centers," remained accessible only to the top layer of the Party apparatus and the government bureaucracy. Instead of upsetting the existing power structures, cybernetics was enrolled to reinforce them.

CyberNewspeak: "The Scientific Management of Society"

The Soviet establishment not only put computer technology to its service; it also successfully adapted cybernetic theory to its needs. In the late 1960s, cybernetic ideas were incorporated into the writings of a leading Party theoretician, the philosopher Viktor Afanas'ev, Deputy Editor of *Pravda* since 1968, who later rose to become Editor-in-Chief of the journal *Kommunist* and eventually Editor-in-Chief of *Pravda*. Adopting terms from cyberspeak, Afanas'ev began talking of "social information" and "the scientific management [*upravlenie*] of society."[108] Instead of exposing the limits on the free circulation of information in the Soviet Union, as Wiener had once hoped, the cybernetic analysis of social processes was now employed to rationalize the management of Soviet society and to ensure its stability.

During the early anti-cybernetics campaign, Soviet critics had attacked cybernetics for being a "technocratic theory."[109] Now the ideological attitude toward technocratic aspirations of cyberneticians was completely reversed. In 1967 the authors of the fifth volume of *Cybernetics—in the Service of Communism* wrote with pride that "the view of society as a complex cybernetic system with a multi-dimensional network of direct and feedback links and a mechanism of optimization, functioning towards a set goal, is increasingly gaining prestige as the main theoretical idea of the 'technology' of managing society."[110] Cyberneticians emphasized Lenin's interest in Taylorism and his attempts to rationalize the organization and functioning of the Soviet apparatus, and portrayed Soviet cybernetics as the heir to this Leninist tradition. Berg's Council on Cybernetics played a crucial role in the ideological rehabilitation of the legacy of Aleksei Gastev and other Soviet pioneers of the "scientific management" movement of the 1920s.[111]

Afanas'ev quickly translated the basic principles of operation of the Soviet government into cyberspeak. He portrayed socialism as "a scientifically controlled society." The government, the Communist Party, and other political and public organizations constituted the controlling subsystem, while the economy, science, and other social activities made up the controlled subsystem. The Party, "the most important element of the scientific control of socialist society," played, of course, the role of the chief controller, whose function was to bring "men's subjective activities into line with the requirements of objective laws."[112] Afanas'ev argued that all managerial activities, from running a factory to directing the building of communism in the Soviet Union, followed the same cybernetic "control cycle":

> The decision has been made, the controlled and controlling systems set in order and regulated so as to maintain and perfect the order, the processes have been checked and corrected, the results summed up by the system of accounting and inspection. On the basis of information about the results another decision is taken and the cycle is resumed.[113]

The flexibility of both newspeak and cyberspeak made this translation incredibly easy: the Party principle of "democratic centralism," for example, could easily be interpreted as control by means of feedback. Afanas'ev formulated the cybernetic approach to the management of society in such a way that it displayed, as the historian David Holloway has put it, "a fundamental congruence" with the Soviet ideological discourse on government:

> In both cases, there is an emphasis on control and management: both are purposive and goal-oriented; both claim to be, in some since, scientific; both underline the need for a systemic or holistic approach; the one seeks policies, the other optimal solutions; the one stresses democratic centralism, the other the hierarchical nature of control systems.[114]

Afanas'ev's concept of the "scientific management of society" fitted well with the pragmatic agenda of Brezhnev's regime. As Holloway has argued, this concept was based on the rationality "appropriate to a society which is regarded as being in a state of equilibrium, and hence differs from the rationality of Stalinist rule, with its goal of transforming Soviet society."[115] Indeed, in Afanas'ev's interpretation, cybernetics was no longer a vehicle of cardinal reform; it was now a system of analytical and technical tools for maintaining the stability of the Soviet economy and society. Quite understandably, Soviet ideologues embraced the former "reactionary pseudo-science"—not because they had been particularly impressed by cyberneticians' mathematical models, but because they had transformed cybernetics into a convenient ideological tool that served a useful political purpose. In Afanas'ev's version, the cybernetic model of society would help make the existing social system function more efficiently without changing its fundamental features. This model promised to find technical solutions for the Soviet Union's social and economic problems without endangering the hierarchies of political power. As Holloway has argued, the cybernetic model emphasized technocratic rationalism but neglected the question of democratic control over the state apparatus:

Through its scientific claims, its instrumental approach and its congruence with the Soviet concept of government, the cybernetic model legitimates the Soviet system as a whole, in the very process of carrying through partial reforms, precisely by pointing to the possibilities that the system offers for scientific and rational government. Therefore, the cybernetic model promises to rationalize the existing system of power relationships, not to destroy it.[116]

The appropriation of cyberspeak by Soviet officials became the subject of thorough ridicule in *Ziiaiushchiie vysoty* [*The Yawning Heights*], a venomous satire of Soviet society written by Aleksandr Zinov'ev, a prominent Soviet logician and an independent-minded thinker, in the mid 1970s. Afanas'ev, with whom Zinov'ev had served on the editorial board of the journal *Problems of Philosophy*, was portrayed in this book as "a very stupid philosopher."[117] Framed as a "scientific" treatise on "socio-mechanics," the first part of Zinov'ev's book parodied Soviet intellectuals' attempts to explain rationally the workings of a socialist regime. If one tried to apply logical deduction to the understanding of society, wrote Zinov'ev, one would quickly make the following discovery:

Deduction is impossible owing to the excess of data, the multiplicity of initial concepts and assumptions, the paucity of deducible consequences, and the practical uselessness of what is deduced. All this has a dispiriting effect on the modern scientist, whose mind has been stuffed full of mathematicization, formalization, model-making, and so on.[118]

Poking fun at Soviet cyberneticians' hopes to improve the government by introducing efficient procedures for collecting and processing information, Zinov'ev observed with sarcasm that higher authorities did not need information at all:

Information, by definition, could never be truthful and complete. No information at all was needed for the normal functioning of society, and the leadership's instinct was correct: to inflate worthless trivia, hush up important events and do all our rethinking for us.[119]

When one of the characters mentioned the government's attempts to "perfect society in such a way that it becomes easier to govern scientifically," another immediately replied: "You surely can't be unaware of the attempts that have been made over the last decade to improve and simplify the apparatus of control? How have they ended? Things are now more confused and tangled than they were before."[120] Zinov'ev explicitly scorned the belief that cybernetics could help bring social harmony by means of some clever control mechanisms. As one of the characters in his book argued, social stability "is only the resultant of all the various forces at work, and can only be achieved if it is in complete accord with their social nature. It is far from being the realization of some ideal cybernetic system of control."[121]

Zinov'ev dismissed the convergence of cyberspeak and newspeak in the official Soviet discourse as "methodological phraseology." He scoffed at "generalizing theories" based on such fashionable concepts as "systems, models, structures, functions, and information," ridiculing their "universal" applicability:

> To get some idea of these generalizing theories, the reader might try, for example, to construct a methodological theory of functions which would embody mathematical functions, a functional approach and the function of the trade unions in the textile industry. In the final analysis, the kaleidoscopic use of words like 'system', 'systematic', 'information', 'structure', 'functional', 'model', and so on, in the powerfully running tide of methodological literature, more often than not merely reflects the feel of the age, and not the results of serious research.[122]

Zinov'ev, the leading Soviet specialist in the philosophical questions of mathematical logic, had once been actively involved with a group of logicians and mathematicians participating in the early cybernetic research. In the late 1950s, he had organized an open seminar on logic at the Academy Institute of Philosophy; several figures prominent in the cybernetics movement had given talks at that seminar, including the philosopher Ernest Kolman, the logician Sof'ia Ianovskaia, the mathematician Aleksandr Esenin-Vol'pin, the linguist Sebasti'an Shaumian, and the mathematician Gelii Povarov.[123] Later, however, Zinov'ev distanced himself from the now-fashionable cybernetics. This move was typical of the early generation of cybernetics enthusiasts, who suddenly found their original ideas turned upside down. Instead of equipping academic discourse with mathematical and logical rigor and precision of formulations, as they once had hoped, cybernetics turned into a flexible ideological tool, another newspeak, only now filled with cybernetic terminology.

The End of the Cybernetics Game

By the early 1970s, the cybernetics movement had changed completely in character. It no longer challenged the orthodoxy; instead, tactical uses of cyberspeak overshadowed the original reformist goals that aspired the first Soviet cyberneticians. Igor' Poletaev (a close associate of Liapunov and the author of the first Soviet book on cybernetics), who had once fought to legitimize cybernetic research, bitterly told his friends in the 1970s: "Now it is I who will say that cybernetics is a pseudo-science."[124] Cybernetics became part of the dominant discourse that early cyberneticians despised, and they no longer wanted to call themselves cyberneticians.

Former leaders of the cybernetics movement grew increasingly disillusioned with the claim of universality of cybernetic methods. "Enough talk about the unity of all control systems and the omnipotence of cybernetics," Poletaev told his colleagues. "It's time to start working, building concrete models, and studying concrete problems. Enough philosophy; let's get to work."[125] The indiscriminate use of cybernetic models without any respect to their validity in specific situations alarmed those mathematicians who recognized the limits of cyberspeak. Citing the infamous project to divert Siberian rivers, Izrail' Gel'fand, a leading specialist in mathematical biology, has argued: "I am convinced that in our computer age only mathematicians can prevent the abuse of 'mathematical methods in . . . ' (biology, medicine, ecology), when only one small, primitive element is taken out of context, and on its basis people try to solve problems which in their essence are not mathematical."[126] In a 1970 samizdat article, Aleksandr Esenin-Vol'pin, a leading specialist in mathematical logic, called "the rapture over mathematical applications" one of the major obstacles in the way of rigorous scientific thought:

> [Natural scientists] realize that their disciplines are insufficiently rigorous, which undermines the reliability of their conclusions, and they are trying, wherever possible, to connect their work with mathematical methods. . . . This is, however, a form of submissiveness. [One must] learn to look at the use of mathematical apparatus in various fields from a critical perspective. . . . Natural scientists' reliance on mathematical rigor has an obvious deficiency: what they constantly use is in fact *applied* mathematics, that is, precisely the area of study where mathematicians say goodbye to rigor, while remaining loyal to mathematical methods in all other respects. Traditional mathematics has achieved its rigor by adopting idealizations, which do not correspond to anything in reality.[127]

After the end of Khrushchev's "thaw," the Soviet scientific community began to polarize. A group of cyberneticians at Moscow University, led by Sergei Iablonskii and Oleg Lupanov, took an openly anti-Semitic stance and almost entirely barred Jews from studying in the Faculty of Mathematics and Mechanics or publishing in *Problems of Cybernetics*, edited by Iablonskii after Liapunov's death in 1973.[128] In March of 1968, at the other pole, 96 Moscow mathematicians, including such leading cyberneticians as

Gel'fand, Liusternik, and Markov, signed an open letter protesting the forced confinement of Esenin-Vol'pin in a mental institution for his dissident activity. Several of the signers lost their jobs as a result of their defense of Esenin-Vol'pin.[129]

After the 1968 Soviet invasion of Czechoslovakia, Soviet authorities launched a crackdown on independent-minded intellectuals and began "purging" Soviet science of dissidents. Several politically active linguists, including Iurii Apresian, Alexander Zholkovsky, and Lidiia Iordanskaia (Igor' Mel'čuk's wife), lost their jobs at linguistics institutions and found a refuge at Informelektro, the information center for the Moscow Institute of Electrical Engineering, where they began working on a machine translation project.[130] The consequences were particularly dramatic for Mel'čuk, who was never inclined to play "according to the rules of the game accepted by the greater part of the linguistic community."[131] Mel'čuk ignored the official hierarchy and deliberately dropped out of the rat race for titles and degrees. His independent style eventually led to a conflict with the political authorities. The publication of his book on the "Meaning—Text" linguistic model, completed in 1968, was delayed 6 years until the book "passed through the censors by accident."[132]

The cybernetics movement split into two opposite branches: while cyberspeak was being appropriated by the academic establishment, some independent-minded cyberneticians came into political conflict with the authorities and lost any opportunity to do cybernetic research in the Soviet Union. Many dissident cyberneticians decided to emigrate. The physicist Valentin Turchin, author of the cybernetic treatise *The Phenomenon of Science* and an associate of Andrei Sakharov, moved to the United States.[133] The engineer Alexander Lerner, author of *Fundamentals of Cybernetics*, struggled with the authorities for 10 years seeking permission to emigrate to Israel. Unable to continue research after losing his job at the Institute of Automation and Remote Control, Lerner organized a series of weekly home seminars for scientist refuseniks (individuals who had been denied exit permits) on the problems of control and mathematical models in biology and medicine—in other words, on cybernetics.[134] Mel'čuk, who was similarly denied research opportunities, wrote to Roman Jakobson in July 1974 that his life in the Soviet Union had become "totally unbearable" and asked Jakobson for help in finding a position at an American university.[135] On 26 January 1976 the *New York Times* published Mel'čuk's open letter protesting against the Soviet persecution of prominent dissident scientists, Andrei Sakharov and Sergei Kovalev. For the authorities, this was the last straw. In March of 1976, despite Mel'čuk's high repute as a scholar and as the author of numerous first-rate publications, his superiors at the Institute of Linguistics gave him a negative evaluation; shortly afterward, they dismissed him from his job. In a new open letter to his Western colleagues, he wrote:

For several years I have had practically no possibility to publish my papers in leading Soviet linguistic journals. . . . The second volume of my monograph *Toward a Theory of Linguistic Models of the Meaning—Text Type* (the product of many years of painstaking work) waited for publication more than 8 years and failed to be, after all, published. I was and am forbidden to teach, to take part in many scientific conventions, to go abroad for contracts with Western colleagues. Immediately after the appearance of my letter in the *New York Times* Soviet linguistic periodicals and publishing houses began suppressing references to my works, acknowledgements by other authors mentioning my name . . . and even my name as the editor or translator. . . . Under such conditions and having no permanent job I am left without the least possibility for normal continuation of my linguistic research.[136]

Nobody wanted to hire Mel'čuk (for obvious reasons), and soon the police informed him that, as a "parasite" and a "sponger," he was to be deported from Moscow and perhaps imprisoned.[137] References to his works disappeared from print; his ideas were thus effectively banned. According to one memoirist, Mel'čuk's expulsion from Soviet linguistics marked the end of the "Silver Age" of Soviet structural linguistics.[138] In May of 1977 Mel'čuk emigrated from the Soviet Union and accepted a position at the University of Montreal. He no longer wanted to play the cybernetics game. He even called one of his own articles on the connection between cybernetics and linguistics "showy and shallow."[139]

In *The Yawning Heights*, Zinov'ev drew a vivid picture of the gradual emasculation of cybernetic discourse and the decline of the cybernetics movement as cybernetics was enrolled to glorify "the ism" (socialism, communism, Marxism-Leninism, etc.):

The Newspaper published an editorial directive *Cybernetics in the Service of the Ism*. . . . [The editorial] made the direct and straightforward statement that the true scientific comprehension of cybernetics was first arrived at by the classic authors of the Ism, who, even though they never heard of cybernetics, had been able to leave some appropriate quotations for posterity. . . . Soon on every street there blossomed Institutes and Laboratories of Cybernetics and the other new sciences which were now of inestimable value in the development of the Ism. . . . The reactionary forces knew from experience that new ideas only begin to bring new support to the Ism once they are hopelessly out of date and have begun to grow boring. . . . Troglodyte was appointed chairman of cybernetics committee. Under his experienced leadership the progressive forces immediately proved that the new ideas upheld the truth of the Ism on its new stage of development, and were beginning to overtake the West on the cybernetic front. . . . "We are all cyberneticists now," [said Teacher]. . . . "It's only recently that we had no more than five or six cyberneticists, and they were all under police surveillance. They'd nearly all done time. Last week we had a symposium and more than a thousand specialists turned up. . . . We are moving into a boom. Things'll be blown up beyond all measure. All manner of rabble will gather round trying to get in on the act. People will write theses, collect titles, decorations, prizes. . . . And then the boom will begin to blow over. In the meantime any scientists worthy of the name will have been eliminated and crushed. Then there'll be a period of total disillusionment. Every idea of any unifying ideological significance will have been exhausted. All that will remain will be the usual official mass phenomenon."[140]

"The opposition must stop decking itself out in alien rags and tatters of science, art and economics," Zinov'ev concluded, summing up the disillusionment of the former reformers. "It must speak out in its own name without resorting to camouflage."[141]

In a way, Soviet cybernetics became a victim of its own success. First, Soviet reformers inflated the meaning of cybernetics, trying to push forward a wide range of innovations under the banner of the cybernetization of Soviet science. Later, the establishment inflated this meaning even further, attempting to secure informational and technological means to support their grip on power. Reformist ideas do not remain such forever: after becoming fashionable, they may turn into another dogma and a basis for new conservatism. When cyberspeak first challenged Stalinist discourse, it was a language of opposition and resistance; later, when cyberspeak replaced newspeak in its dominant role, it had nothing new to say.

Conclusion
Soviet Cybernetics: Prometheus or Proteus?

Language is a tool of communication.
—Joseph Stalin

It isn't language that is a tool of the poet, but rather the poet who is a tool of language.
—Joseph Brodsky

Cyberspeak as a Carnival Language

This study has examined the development of cybernetics in the Soviet Union from an object of unbridled ideological criticism during the anti-cybernetics campaign of the early 1950s to a vehicle of reform in the post-Stalinist system of science in the late 1950s to a fashionable trend in the 1960s to a convenient tool of bureaucracy in the early 1970s. No single agency controlled Soviet cybernetics. It was contested, fought over, reshaped, and put into service by various groups with diverse research interests and political agendas. The cybernetic discourse was composed of multiple divergent discursive trends that used the same language. The many conflicting aspects of cyberspeak—its claims to universality and rigor, its flexibility and ambiguity, its metaphorical man-machine analogies and precise mathematical calculations—gave rise to very diverse and often contradictory uses. The military and pacifists, technocrats and environmentalists, dissidents and Party bureaucrats alike spoke the language of cybernetics. Like any other language, cyberspeak could express very different, and sometimes opposite, views.

Unlike many traditional analyses of power/knowledge discourse that focus on the conflict between opposing discourses, this study draws attention to the common features of the language of cybernetics and the Soviet ideological language. Soviet cybernetics as a discourse modeled itself on newspeak—first as an enemy, then as a challenger, later as a substitute—and employed the same discursive techniques that made the Soviet ideological discourse flexible, adaptable, and virtually universal. Like newspeak, whose dogmatic formulas allowed for a wide range of convenient interpretations, cyberspeak created a room for intellectual freedom by offering a large variety of techniques of quantification, formalization, and computer modeling for any subject. Like the language of Soviet pseudo-Marxism, cyberspeak combined polysemous terminology with flexible rules of reasoning. Both newspeak and cyberspeak imposed limitations on how to speak but left much room for what could be said as long as it was said in the right way. Both Soviet political slogans and formal cybernetic models often functioned in a "poststructuralist" way: as material for play, metaphor, and ironic subversion.

While cyberspeak mirrored many features of the dominant ideological discourse, this "mirror" was a distorted one. One could interpret the cybernetic discourse as a carnival-like inversion of dominant stereotypes: cyberspeak parodied the scientistic vocabulary of dialectical materialism, mockingly reflected the Soviet obsession of technology, and translated mathematical formulas into universal philosophical claims and vice versa.[1] As the biologist Inga Poletaeva (Igor' Poletaev's daughter) has put it: "It was a game. We ridiculed definitions given by official philosophy. It was fun, a gymnastics for the mind."[2]

While trying to build a "scientific" alternative to the official ideological discourse, Soviet cyberneticians undermined not only dominant ideological stereotypes but also some dominant myths of scientific discourse. Looking for rigorous, "precise" definitions of fundamental concepts in their disciplines, cybernetic biologists, physiologists, and linguists often realized that many basic notions of cybernetics, mathematics, and natural science had no accepted definitions. For example, unable to give a precise definition of meaning, the linguists Alexander Zholkovsky and Igor' Mel'čuk suggested that meaning should perhaps be considered "indefinable," like "such indefinable concepts as the set, the point, information, energy, or the elementary particle."[3] Zholkovsky and Mel'čuk seemed to have turned upside down a common stereotype of the "exact sciences" to send an implicit message: we want to make our theory as rigorous as mathematics, physics, or information theory, and since those "exact" sciences see no need to define their basic concepts, neither do we. When they learned that information theory actually provided a definition for the notion of information, they quickly transformed it into a "rigorous" definition of the "indefinable" concept of meaning.

Despite its use of mathematical and logical concepts, the cybernetic discourse was characterized by uncertainty, ambiguity, indeterminacy, and inconsistency. Speakers often had neither full control over nor complete understanding of meaning. Although individual cyberneticians skillfully manipulated the language of cybernetics, they were not able to limit the range of interpretations of cybernetic ideas: it was as if the cybernetic discourse as a whole articulated itself through various groups of scientists with all of its possible political and intellectual ramifications.

Cyberspeak eventually began to control its masters in the same way as newspeak shaped the identity of Soviet citizens. Self-identification in Stalinist society, Stephen Kotkin argues, required mastery of a new vocabulary of Bolshevik terms. Only by "speaking Bolshevik" could people enter the public realm and express their concerns. The very act of speaking this language served as an indication of loyalty, and learning how to speak Bolshevik became a crucial social skill. Self-identification through the speaking of Bolshevik then became something of a self-fulfilling prophecy. While people were mastering Bolshevik to express their social identity in acceptable terms, their identity was reshaped: speaking Bolshevik became its pivotal part. People were trying to manipulate the Bolshevik language as a means of resistance, but they themselves became instruments of state control. They perpetuated this "game of social identification" far beyond the official settings and into their daily lives. All ways of speaking about oneself "came to be refracted through the inescapable political lens of Bolshevism," argues Kotkin, seeing the roots of the strength of Stalinism precisely in this discursive mechanism.[4]

The game of "cybernetic identification" produced a similar effect: Soviet cyberneticians began to take seriously the parodic language they had forged. After they had fashioned cyberspeak as a universal, objective, precise language, it became very difficult for them to step outside the cybernetic discourse and critically examine its limitations. Hailed as a language of truth and objectivity, cyberspeak eventually became a shadow of its formal object of ridicule, newspeak.

Ironically, Soviet scientists' search for a "non-ideological," "objective" language brought them back to an ideology-laden discursive ground, which they had never really left. Soviet cyberneticians effectively employed the same newspeak strategies as their opponents. Manipulating positive and negative evaluative meanings of ideologemes, cyberneticians ridiculed the "universality" of dialectical materialism, but they tried to replace it with equally "universal" cyberspeak. They described cyberspeak as both infinitely flexible (to establish the meta-scientific status of cybernetics and to bring under the cybernetic umbrella a great number of disciplines) and thoroughly rigorous (to justify the cybernetic claim to objectivity). Soviet cybernetics formed its value system by turning some traditional evaluative meanings of newspeak upside down. Ambiguity was turned into flexibility, rigid formulas into precise definitions, and rule-based formal reasoning into an instrument of intellectual freedom.

Cyberspeak as an Instrument of Freedom

Speaking at the Institute of Foreign Languages in September of 1958 during one of his first public appearances in Moscow after almost 40 years as an émigré, Roman Jakobson quoted Catherine the Great: "Freedom is the right to do whatever is permitted by the law."[5] Social norms have a dual nature, both restrictive and liberating, and Soviet cyberneticians interpreted formal rules—both in scientific thinking and in scientific practice—as an instrument of liberation.

Soviet cyberneticians viewed cyberspeak as a means for overcoming the limitations of dogmatic conceptual frameworks established by dominant Stalinist schools in biology, physiology, and linguistics. A formal definition of the linguistic norm offered by Soviet cybernetic linguists provides insight into this function of cyberspeak. Perhaps inspired by Jakobson, the structural linguist Isaak Revzin of the Institute of Foreign Languages described the linguistic norm as consisting of a set of permissions and a set of prohibitions. Two interpretations of the norm would then be possible: (1) All that is not explicitly permitted (that is, specified in a normative dictionary or grammar) is prohibited. (2) All that is not explicitly prohibited is permitted. The first interpretation, Revzin argued, was characteristic of normative stylistics, in which prohibitions are determined by "a certain group of writers who become a kind of 'priests' or guardians of the linguistic norm, and their books are universally recognized as collections of correctly constructed, exemplary sentences." One can easily recognize in this description not only the "guardians" of linguistic orthodoxy but also the notorious "classics of Marxism-Leninism," whose exemplary quotations were employed to set norms in every academic field. The second, broader interpretation of the linguistic norm, Revzin wrote, is "often taken in poetry; although poets frequently violate even explicit prohibitions."[6]

Poetry, an archetypal realm of freedom in which "all that is not explicitly prohibited is permitted," may be seen as a metaphor for Soviet cybernetics. Poetry opens up room for freedom precisely because of the rigidity of the constraints imposed by the poetic form. Overcoming limitations of the form, poets create their own worlds, in which, Revzin wrote, certain "expressions, which had no meaning in [ordinary] language before, now become justified." Revzin gave meaning to Noam Chomsky's famous example of a syntactically correct but meaningless sentence, "Colorless green ideas sleep furiously," by turning it into a poetic metaphor:

An idea furiously sleeps;
It tosses and turns in bed,
It pounds, it screams, it weeps,
And whispers in my head.[7]

Similarly, Revzin argued, "unusual statements that formulate new truths in science" were justified.[8] Soviet cyberneticians seemed to justify their own "new truths" in the same way: they employed formal discursive rules not so much to make their reasoning "exact" as to free themselves from Stalinist dogmas.

Soviet cybernetic biologists, physiologists, and linguists were often more inspired by the distinct academic standards of mathematical discourse than by the power of mathematical formalisms themselves. They discovered that mathematicians' discursive style was very different from their own. The mathematicians' meticulous observation of formal rules in conducting seminars, leading discussions, and writing papers proved liberating rather than restrictive: all that was not explicitly prohibited was permitted. Revzin recalled the deep impression made on him by the mathematician Vladimir Uspenskii's style of conducting seminars on mathematical linguistics at Moscow University:

> The pedantic and formal manner that was characteristic of Uspenskii's every statement and every action was not at all boring; . . . it was jovial and jocular and was accompanied by exceptional indulgences: during the seminar, it was permitted to interrupt the speaker, ask questions, go to the blackboard, and start an argument; it was even permitted not to understand the speaker and be proud of this. All this

was unheard-of among linguists; it looked especially striking at the Philology Faculty [of Moscow University] and was totally unthinkable at our Institute of Foreign Languages.[9]

Claiming mathematics and natural science as their ideal, Soviet cyberneticians imitated not so much the rigor of the "exact sciences" as their discursive style, their critical mode of speaking, and their appeal to objectivity.

The limited capacity of the language of cybernetics as a conceptual tool was well compensated for by its significant social role. As a language of truth and objectivity, cyberspeak was often used as a discursive weapon against dominant schools in various disciplines. In opposition to the orthodox schools of Pavlovians in physiology and Lysenkoites in biology, with their vague, imprecise language and their dogmatic, fixed content, there emerged cybernetic physiology and cybernetic biology, with their formal, "precise" language and their very flexible content. Formal language imposed some severe constraints on discourse: not everything could be expressed in a given formalism, and many things had to be left out. On the other hand, formal language proved capable of describing things that could not be talked about in ordinary language because of various social and political taboos.

By adopting the language of cybernetics, Soviet scientists effectively got rid of a whole set of categories and principles characteristic of the dominant scientific and philosophical discourse. By reducing physiological and biological phenomena to their computer models, Soviet cyberneticians were able to eliminate Pavlovian and Lysenkoist dogmas as "not amenable to formalization." As with Ockham's Razor, they cut off the "superfluous" concepts. Under the banner of clarification and formalization of scientific concepts, they introduced an entirely new conceptual framework. The cybernetic models of communication as information exchange, of human behavior as a feedback mechanism, and of the human brain as an analog to computer, however simplistic, supplanted yet more simplistic ideas advanced by the orthodox Pavlovians in physiology and the Lysenkoites in biology. Cybernetic models of government, however utopian and technologically infeasible, threatened to upset existing power structures and to take some authority away from the Party and the government bureaucracy, even if this involved trusting this authority to a soulless machine.

I would argue that the transitions from the Stalinist era to the Khrushchev period and then to the Brezhnev regime did not alter the basic negotiating role of ideological discourse in Soviet science, and that it caused changes only in the language of negotiation between scientists and politicians. In the mid 1950s, after the death of Stalin, when the old discursive order of the Stalinist regime was undermined, Soviet scientists and engineers attempted to replace the old ideological language (newspeak) with cyberspeak as a new mediating language. The use of cyberspeak gave scientists a great advantage, for they retained control over its vocabulary. Cyberspeak both provided a basis for dialogue among various scientific disciplines and facilitated negotiations between scientists and politicians. The mediating political role of the language of cybernetics and its mediating cognitive role reinforced each other.

Soviet cybernetics emerged as a project of reforming Soviet science—politically and intellectually—after the years of Stalinism. This reform developed, however, along the familiar lines of replacing old bad dogmas with new good ones. When cybernetics became fashionable, people began jumping on the cybernetic bandwagon, much as earlier they had jumped on the armored locomotive of dialectical materialism. In this sense, the transition from the Stalin era to the Khrushchev and Brezhnev periods did not bring with it a fundamental shift from "ideology-laden" science to "ideology-free," "objective" research; rather, it brought a change in the basic negotiating language from newspeak to cyberspeak.

Soviet cyberneticians tried to make cyberspeak, a grotesque imitation of the dominant languages of politics and science, into a language of intellectual resistance. They aspired to defeat the Soviet ideological discourse by adopting the discursive strategies of newspeak, and their weapon eventually turned against them. Parodic newspeak could hardly become an effective vehicle of reform. As an inverted image of newspeak, cyberspeak proved to be tied to the Soviet ideological discourse much more closely than reformer cyberneticians were ready to admit. Instead of using cyberspeak as an unproblematic rhetorical tool, cyberneticians themselves became tools of the metamorphosing cybernetic discourse. While trying to imitate and undermine newspeak at the same time, Soviet cyberneticians ended up talking CyberNewspeak and perpetuating official ideological discourse.

The great variability and flexibility of Soviet cybernetics, which served many masters and always escaped a narrow definition, prompts a comparison with Proteus. This mythological Greek prophet, who knew all things in the past, the present, and the future, was reluctant to tell anyone his prophecies and preferred to avoid visitors by assuming various shapes. Soviet cyberneticians, in contrast, tried to disseminate their "prophecies" as widely as possible, but they used the same Protean strategy of endless variation. This Protean nature allowed cybernetics to be infinitely malleable and—for this reason—seemingly universal.

The story of Soviet cybernetics also evokes the fate of another personage of Greek mythology: the titan Prometheus. Aeschylus's *Prometheus Bound* tells the famous tale in which Prometheus steals fire, a symbol of wisdom and civilization, from the gods and brings it to the mankind. Prometheus, who revolted against the will of gods and was punished by them, became a symbol of self-sacrificing rebellion. Like Prometheus, cybernetics brought people a gift, the language of cybernetics, and similarly fell victim to its own rebellion. Paradoxically, Soviet cybernetics showed both Protean and Promethean qualities: its story is both heroic and ironic, both inspiring and disappointing, both magnificent and carnivalesque.

But is the story of Soviet cybernetics unique? If the universalistic ambitions of Soviet cyberneticians were fueled by their opposition to the dominant ideological discourse, what fueled the similar universalistic ambitions of Western cyberneticians? If the Marxist faith in the power of technology gave credence to Soviet cyberneticians' claims of computer-based objectivity, what sustained similar claims made by their Western colleagues? Instead of contrasting Soviet cybernetics with its Western counterpart as products of opposing ideologies, I would suggest that cybernetic discourses on both sides of the Iron Curtain served very similar ideological purposes.

Cyberspeak as a Universal Language of Capitalism and Communism

Recent historiography tends to deconstruct the stereotypical ideological differences and to emphasize instead the discursive and structural similarities between the former Cold War opponents. Susan Buck-Morss has argued that the Cold War enemies shared the same "dreamworlds," the utopian visions of human happiness achieved through technological progress.[10] With all the proclaimed differences in political ideologies, the opposing regimes placed equally heavy emphasis on the development of science and technology, and each integrated technocratic dreams into its agenda. Walter McDougall has argued that the mobilization of science in the interest of national security resulted in the political rise of technocratic bureaucracies on both sides of the Iron Curtain.[11] Historians of American science often talk about a "strategic alliance" (Paul Hoch), "increased integration" (Daniel Kevles), or a "mutual embrace" (Sylvan Schweber) of the military and the scientists involved in defense research.[12] Russian historians, for their part, speak of "the coalescence of military, government, and Party leadership" (I. Bystrova) and of a "symbiosis" between the Party/state apparatus and the Soviet scientific community (Nikolai Krementsov).[13]

Despite the different character of political, social, and economic forces in the Soviet Union and the United States, American and Soviet scientists chose very similar discursive strategies in order to adapt to the dominant political culture. For example, while the Soviets shifted the boundary between knowledge and ideology back and forth, the Americans manipulated the notions of "basic" and "applied" science as the leaders of the National Science Foundation switched back and forth between the "rhetoric of insulation" (an appeal to the supposedly apolitical character of basic science) and the "rhetoric of relevance" (an argument for the vital importance of science for the interests of national defense).[14] The sociologist Thomas Gieryn has argued more generally that scientists are often engaged in "boundary-work," the drawing of a rhetorical boundary between science and non-science. In particular, in order to protect their autonomy, scientists tend to oscillate between two opposing discursive strategies:

> If the stakes are autonomy over scientists' ability to define problems and select procedures for investigating them, then science gets "purified," carefully demarcated from all political and market concerns, which are said to pollute truth; but if the stakes are material resources for scientific instruments, research materials, or personnel, science gets "impurified," erasing the borders or spaces between truth and policy relevance or technological panaceas.[15]

When maneuvering between the two dominant ideological trends ("Criticize and Destroy!" and "Overtake and Surpass!"), Soviet scientists often resorted to the narrow, "de-ideologized" vision of science. This strategy had remarkable parallels in the American case. As Jessica Wang has argued, American scientists in the early postwar years, under the political pressure of domestic anti-communism, turned away from a rhetorical style of the progressive left, which emphasized the basic principles of civil liberty, and tended to rely instead on "internal negotiations within government agencies to achieve more limited policy goals."[16] These scientists' initial vision of science as an international endeavor gave way to back-room bargaining with government officials over funding of specific projects, often justified as countermeasures to the "Soviet threat." After Sputnik, the American slogan "Catch up with the Russians!" completed the picture of two Cold War rivals chasing each other's tails.

The use of cyberspeak was among the most popular discursive strategies of both American and Soviet scientists. Military researchers on both sides of the Iron Curtain integrated cybernetic control systems into their weapons and conceptualized the political and social world as a closed, computable system subject to manipulation and control. If cyberspeak embodied the ideological stereotypes of the Cold War, as Paul Edwards has argued, these stereotypes turned out to be remarkably similar across political borders.[17]

Both in the Soviet Union and in the United States, however, liberal thinkers also actively employed cyberspeak. Norbert Wiener believed that his cybernetic analysis would expose the flaws of both capitalism and communism.[18] The dissident Valentin Turchin hoped that the Soviet regime could be reformed along the rational guidelines of cybernetics.[19] While the military interpreted cybernetic feedback as a mechanism for controlling the execution of commands, liberals viewed it as a procedure for ensuring democratic participation in decision making.

Both capitalist corporations and communist bureaucracies were fascinated by the prospects of automated management and rational control. The idea of solving political and organizational problems through computerized information processing had equally powerful appeal to technology-minded managers from the "bourgeois" middle class and to those from the ranks of the Communist Party. The same principles of feedback control and optimal planning were disseminated in the United States under the name of "management science" and in the Soviet Union under the banner of "economic cybernetics."[20]

American and Soviet cybernetic control systems shared both their strengths and their inherent deficiencies. One Western observer noted that "the wonder is not that the [Soviet economic information] system works badly but that is works at all," and added: "To be fair, I must admit that during several weeks' work with large U.S. military logistics systems, I was filled with the same wonder—albeit of a lesser order of magnitude."[21] Cybernetics seems to have served different political ideologies equally well, or maybe equally badly. A capitalist dystopia turned a communist utopia and ended up a pragmatic management device.

The Cold War enemies not only shared their devotion to the language of cybernetics; they also often resorted to the same rhetorical techniques of newspeak. Depicted by Orwell as a phenomenon deeply alien to Western democracies, newspeak nevertheless found numerous followers among Western politicians (and scientists). For example, employing the typical newspeak strategy of inverting evaluative meanings, Western politicians can easily switch between appeals to "the popular vote" and accusations of "trailing the polls," depending on whether the polls favor them or their opponents. In 1988, when the Soviet Union was still a superpower, Mikhail Heller bitterly commented on the spread of newspeak around the globe:

> The nature of the Soviet language has enabled it to become a universal language, the Esperanto of the second half of the twentieth century. Today the world wants to dress in the American way and to watch American films. But the world speaks in the Soviet way and gives expression to its fears and hopes in the Soviet language.[22]

Even before he published *Nineteen Eighty-Four*, Orwell made the following comment about the contemporary *English* usage:

> The words *democracy, socialism, freedom, patriotic, realistic, justice,* have each of them several different meanings which cannot be reconciled with one another. In the case of a word like *democracy,* not only is there no agreed definition, but the attempt to make one is resisted from all sides. It is almost universally felt that when we call a country democratic we are praising it: consequently the defenders of every kind of régime claim that it is a democracy, and fear that they might have to stop using the word if it were tied down to any one meaning.[23]

Erich Fromm wrote: "The reader will find many other features of our present Western society in Orwell's description in *1984*, provided he can overcome enough of his own 'doublethink.'"[24]

Now, with the Soviet Union gone, newspeak is no longer in fashion, but its discursive techniques live on in cyberspeak. Identifying with the computer as "the second self," the world now expresses its fears and hopes in the language of cybernetics.[25] Cyberspeak has power over us: it is now no more realistic to speak of dispensing with cyberspeak than to speak of dispensing with computers. By understanding the discursive mechanisms of cyberspeak, however, we can acknowledge its conceptual limitations. By taking cyberspeak a bit less seriously, as a language of metaphor, irony, and subversion, we could try again to make it an instrument of intellectual freedom.

This Page Intentionally Left Blank

Notes

The following abbreviations are used in the notes:

ARAN	Arkhiv Rossiiskoi Akademii Nauk (Russian Academy of Sciences Archive), Moscow
ITMVT	Institut tochnoi mekhaniki i vychislitel'noi tekhniki (Institute of Precise Mechanics and Computer Technology)
MC	manuscript collection
RGANI	Rossiiskii gosudarstvennyi arkhiv noveishei istorii (Russian State Archive of Contemporary History), Moscow
RGASPI	Rossiiskii gosudarstvennyi arkhiv sotsial'no-politicheskoi istorii (Russian State Archive of Socio-Political History), Moscow
TsAODM	Tsentral'nyi arkhiv obshchestvennykh dvizhenii Moskvy (Central Archive of Social Movements of Moscow), Moscow

The following abbreviations are used in Russian archival citations:

f.	*fond* (collection)
op.	*opis'* (inventory)
d.	*delo* (folder)
l.	*list* (page)

The Library of Congress transliteration system is used, except for those proper names that are customarily used in English in other forms. All translations, unless otherwise noted, are the author's.

Most Russian journals are organized by year and issue number, with no volume number. Citations of most works in non-Russian journals include both a volume number and an issue number.

Variations in the styling of Russian names are attributable to variations in the original publications.

The locations of publishing houses that may be unfamiliar to Western readers are given.

Notes to Introduction

1. Françoise Thom, *Newspeak: The Language of Soviet Communism*, tr. K. Connelly (Claridge, 1989), pp. 111, 211.

2. Geoffrey Bowker, "How to Be Universal: Some Cybernetic Strategies, 1943–70," *Social Studies of Science* 23 (1993), p. 117.

3. See Norbert Wiener, *Cybernetics, or Control and Communication in the Animal and the Machine* (MIT Press, 1948).

4. On Western cybernetics, see Paul Edwards, *The Closed World: Computers and the Politics of Discourse in Cold War America* (MIT Press, 1996); Peter Galison, "The Ontology of the Enemy: Norbert Wiener and the Cybernetic Vision," *Critical Inquiry* 21 (1994): 228–266; Donna J. Haraway, "A Cyborg Manifesto: Science, Technology, and Socialist-Feminism in the Late Twentieth Century," in Haraway, *Simians, Cyborgs, and Women* (Routledge, 1991); Steve J. Heims, *John von Neumann and Norbert Wiener: From Mathematics to the Technologies of Life and Death* (MIT Press, 1980); Heims, *Constructing a Social Science for Postwar America: The Cybernetics Group, 1946–1953* (MIT Press, 1993); David A. Mindell, 'Datum for Its Own Annihilation': Feedback, Control, and Computing, 1916–1945, Ph.D. dissertation, Massachusetts Institute of Technology, 1996.

5. Vladimir Bukovskii, "Iz knigi 'I vozvrashchaetsia veter,'" in Aleksandr S. Esenin-Vol'pin, *Filosofiia. Logika. Poeziia. Zashchita prav cheloveka: Izbrannoe* (Moscow: RGGU, 1999), p. 417.

6. Mikhail N. Epstein, *After the Future: The Paradoxes of Postmodernism and Contemporary Russian Culture* (University of Massachusetts Press, 1995), pp. 138–139.

7. William Griffith, "On Esoteric Communications," *Studies in Comparative Communism* 3 (1970), p. 54.

8. Paul R. Josephson, *New Atlantis Revisited: Akademgorodok, the Siberian City of Science* (Princeton University Press, 1997), p. 123.

9. "Kibernetika," in *Kratkii filosofskii slovar'*, ed. M. Rosental' and P. Iudin (Moscow: Gospolitizdat, 1954), pp. 236–237.

10. Al'bert M. Molchanov, "Limitiruiushchie faktory (po I. A. Poletaevu) i printsip Le-Shatel'e," in *Ocherki istorii informatiki v Rossii*, ed. D. Pospelov and I. Fet (Novosibirsk: OIGGM SO RAN, 1998), p. 402.

11. Vladimir Baranov, "Rasprostranenie doktrin i kul'turnye stereotipy," http://www. computerra.ru/offline/1997/225/915.

12. See, e.g., Alexander Vucinich, *Empire of Knowledge: The Academy of Sciences of the USSR (1917–1970)* (University of California Press, 1984).

13. See Paul R. Josephson, "'Projects of the Century' in Soviet History: Large-Scale Technologies from Lenin to Gorbachev," *Technology and Culture* 36 (1995), no. 3: 519–559.

14. See David Holloway, "Physics, the State, and Civil Society in the Soviet Union," *Historical Studies in Physical and Biological Sciences* 30 (1999), no. 1: 173–192.

15. See Loren R. Graham, *What Have We Learned about Science and Technology from the Russian Experience* (Stanford University Press, 1998), chapter 3.

16. See Loren R. Graham, *Science, Philosophy, and Human Behavior in the Soviet Union* (Columbia University Press, 1987).

17. See David Joravsky, *The Lysenko Affair* (Harvard University Press, 1970).

18. See Mark B. Adams, Networks in Action: The Khrushchev Era, the Cold War and the Transformation of Soviet Science, Trondheim Studies on East European Cultures and Societies, no. 3 (2000); Adams, "Science, Ideology, and Structure: The Kol'tsov Institute, 1900–1970," in *The Social Context of Soviet Science*, ed. L. Lubrano and S. Solomon (Westview, 1980).

19. Nikolai Krementsov, *Stalinist Science* (Princeton University Press, 1997), p. 6.

20. See Alexei Kojevnikov, "President of Stalin's Academy: The Mask and Responsibility of Sergei Vavilov," *Isis* 87 (1996), no. 1: 18–50; Kojevnikov, "Rituals of Stalinist Culture at Work: Science and the Games of Intraparty Democracy Circa 1948," *Russian Review* 57 (1998), no. 1: 25–52.

21. On historiographic debates in the studies of Soviet science, see Slava Gerovitch, "Writing History in the Present Tense: Cold War–Era Discursive Strategies of Soviet Historians of Science and Technology," in *Universities and Empire*, ed. C. Simpson (New Press, 1998); Alexei Kojevnikov, "Toward a Post-Cold War Historiography (a Reply to David Joravsky)," *Russian Review* 57 (1998), no. 3: 455–459; Susan Gross Solomon, "Reflections on Western Studies of Soviet Science," in *The Social Context of Soviet Science*, ed. Lubrano and Solomon.

22. Stephen Kotkin, *Magnetic Mountain: Stalinism as a Civilization* (University of California Press, 1995), p. 23.

23. Michel Foucault argued that power and knowledge produce each other through the mechanism of "discourses of truth": power determines what counts as true knowledge, while the authority of knowledge justifies particular regimes of power. Power is always mediated by discourse, and it needs to produce discourses of truth to survive. "What makes power hold good, what makes it accepted, is simply the fact that it doesn't only weigh on us as a force that says no, but that it traverses and produces things, it induces pleasure, forms knowledge, produces discourse. It needs to be considered as a productive network which runs through the whole social body, much more than a negative instance whose function is repression." (Foucault, *Power/Knowledge*, ed. C. Gordon, Pantheon, 1980, p. 119)

Notes to Chapter 1

1. Quoted in V. O. Pechatnov, "'Strel'ba kholostymi': Sovetskaia propaganda na Zapad v nachale kholodnoi voiny (1945–1947)," in *Stalinskoe desiatiletie kholodnoi voiny*, ed. I. Gaiduk et al. (Moscow: Nauka, 1999), p. 115.

2. D. Gil'bert and V. Akkerman [i.e., Hilbert and Ackermann], *Osnovy teoreticheskoi logiki*, ed. S. Ianovskaia (Moscow: Izdatel'stvo inostrannoi literatury, 1947), p. 250.

3. Ibid., pp. 280–281.

4. Vasilii P. Tugarinov and Leonid E. Maistrov, "Protiv idealizma v matematicheskoi logike," *Voprosy filosofii* 1950, no. 3, p. 338.

5. Ibid., pp. 331–332, 337.

6. George Orwell, "Appendix: Principles of Newspeak," in *Nineteen Eighty-Four* (Signet Classic, [1949] 1981), p. 246.

7. See Richard D. Anderson Jr., "'Look at All Those Nouns in a Row': Authoritarianism, Democracy, and the Iconicity of Political Russian," *Political Communication* 13 (1996), no. 2: 145–164; Mikhail N. Epstein, *After the Future: The Paradoxes of Postmodernism and Contemporary Russian Culture* (University of Massachusetts Press, 1995), chapter 4; William Griffith, "On Esoteric Communications," *Studies in Comparative Communism* 3 (1970), no. 1: 47–54; Mikhail Heller, *Cogs in the Soviet Wheel: The Formation of Soviet Man*, tr. D. Floyd (Collins Harvill, 1988), chapter III-6; Kotkin, *Magnetic Mountain*; N. A. Kupina, *Totalitarnyi iazyk: Slovar' i rechevye reaktsii* (Ekaterinburg and Perm': Izdatel'stvo Ural'skogo universiteta, 1995); Leonid D. Rzhevskii, *Iazyk i totalitarizm* (München: Institute for the Study of the History and Institutions of the USSR, 1951); Andrei Sinyavsky, *Soviet Civilization: A Cultural History*, tr. J. Turnbull with N. Formozov (Arcade, 1990), chapter 7; Thom, *Newspeak*; Michael Waller, "The -Isms of Stalinism," *Soviet Studies* 20 (1968), no. 2: 229–234.

8. See R. N. Carew Hunt, *A Guide to Communist Jargon* (Macmillan, 1957); Nikolai Krementsov, "Newspeak: A Glossary," in *Stalinist Science* (Princeton University Press, 1997); V. M. Mokienko and T. G. Nikitina, *Tolkovyi slovar' iazyka Sovdepii* (St. Petersburg: Folio-Press, 1998); Il'ia Zemtsov, *Lexicon of Soviet Political Terms*, ed. G. Hammerman (Hero Books, 1984).

9. See Mark B. Adams, "Science, Ideology, and Structure: The Kol'tsov Institute, 1900–1970," in *The Social Context of Soviet Science*, ed. Lubrano and Solomon.

10. See chapter 4 of Epstein, *After the Future*.

11. Stenogramma zasedaniia filosofskogo seminara Matematicheskogo instituta Akademii nauk SSSR, 4 March 1954 (ARAN, f. 383, op. 1, d. 325, l. 51).

12. Ibid., l. 57.

13. Iosif V. Stalin, "Rech' na predvybornom sobranii izbiratelei Stalinskogo okruga goroda Moskvy 9 fevralia 1946 g." (1946), in Stalin, *Sochineniia*, volume 3 [XVI], ed. R. McNeal (Hoover Institution, 1967), p. 19.

14. Quoted in D. G. Nadzhafov, "Antiamerikanskie propagandistskie pristrastiia stalinskogo rukovodstva," in *Stalinskoe desiatiletie kholodnoi voiny: fakty i gipotezy*, ed. I. Gaiduk et al. (Moscow: Nauka, 1999), p. 137.

15. "Postanovlenie Uchenogo soveta Instituta filosofii," 27 May 1952 (ARAN, f. 1922, op. 1, d. 538, l. 9). See also "Kratkii obzor deiatel'nosti zhurnala 'Voprosy filosofii,'" 12 September 1953 (ARAN, f. 499, op. 2, d. 24, ll. 15–42).

16. David Joravsky, *Russian Psychology: A Critical History* (Blackwell, 1989), p. 406.

17. On the Lysenko controversy, see Graham, *Science, Philosophy, and Human Behavior in the Soviet Union*, chapter 4; Joravsky, *The Lysenko Affair*; Nikolai Krementsov, *Stalinist Science*; Zhores A. Medvedev, *The Rise and Fall of T. D. Lysenko* (Columbia University Press, 1969); Valery N. Soyfer, *Lysenko and the Tragedy of Soviet Science*, tr. L. Gruliow and R. Gruliow (Rutgers University Press, 1994).

18. Kirill Rossianov, "Editing Nature: Joseph Stalin and the 'New' Soviet Biology," *Isis* 84 (1993), no. 4: 728–745.

19. Vladimir P. Vizgin, "Spasennaia dvazhdy: Sovetskaia teoreticheskaia fizika mezhdu filosofiei i iadernym oruzhiem," in *Istoriia sovetskogo atomnogo proekta* vyp. 1, ed. V. Vizgin (Moscow: Ianus-K, 1998). See also Kojevnikov, "President of Stalin's Academy," esp. pp. 43–47. On the conflict between the Academy group and the University group, see Gennadii Gorelik, "Fizika universitetskaia i akademicheskaia," *Voprosy istorii estestvoznaniia i tekhniki* 1991, no. 1: 15–32.

20. Kojevnikov, "President of Stalin's Academy," p. 38.

21. See Gennadi Kostyrchenko, *Out of the Red Shadows: Anti-Semitism in Stalin's Russia* (Prometheus Books, 1995).

22. See Alexander Vucinich, *Empire of Knowledge: The Academy of Sciences of the USSR (1917–1970)* (University of California Press, 1984), pp. 210–247.

23. For a general overview of ideological debates in various disciplines, see Graham, *Science, Philosophy, and Human Behavior*.

24. Graham, *Science, Philosophy, and Human Behavior*, chapter 10.

25. In the postwar period, historians largely gave up Marxist sociological analysis, developed in the 1920s and 1930s and exemplified by Boris Hessen's famous 1931 paper on the social and cultural roots of Newton's *Principia*. In an attempt to protect both their subject from "ideologization" and themselves from political complications, Soviet historians now favored strict internalism, which lifted scientific knowledge out of its political and sociocultural context. On Soviet writings on the history and social study of science, see Slava Gerovitch, "Writing History in the Present Tense: Cold War-Era Discursive Strategies of Soviet Historians of Science and Technology," in *Universities and Empire*, ed. C. Simpson (New Press, 1998); Loren R. Graham, *Science in Russia and the Soviet Union* (Cambridge University Press, 1993), chapter 7.

26. See Alexei Kojevnikov, "Dialogues about Power and Knowledge in Totalitarian Political Culture," paper presented at conference on Physicists in the Postwar Political Arena, Berkeley, January 1998—esp. section 5, "Drawing the Boundary between Ideology and Science," which was omitted from the published version.

27. See Graham, *Science in Russia*, chapter 8; Alexei Kojevnikov, "Dialogues about Knowledge and Power in Totalitarian Political Culture," *Historical Studies in Physical and Biological Sciences* 30 (1999), no. 1: 227–247.

28. In French semiotics, the study of various modes of signification has been a major tool of cultural analysis. Claude Lévi-Strauss coined the term "floating signifier," and Roland Barthes the term "empty signifier." While structuralist semioticians emphasize the connection, however arbitrary, between the signifier and the signified, poststructuralists are interested specifically in those cases when signifiers become detached from the signified and begin to "float," "slide," or engage in "free play." Most recently, these terms have been floating in the postmodernist literature inspired by the writings of Jacques Derrida and Jacques Lacan.

29. Rachel Walker, "Marxism-Leninism as Discourse: The Politics of the Empty Signifier and the Double Bind," *British Journal of Political Science* 19 (1989), p. 163.

30. Ibid., p. 164.

31. Epstein, *After the Future*, pp. 107–108.

32. Orwell, "Appendix: Principles of Newspeak," p. 249.

33. Thom, *Newspeak*, pp. 28–31.

34. Compare the Russian words *razvedchik* and *shpion*; see ibid., p. 29.

35. Kupina, *Totalitarnyi iazyk*, pp. 24–27.

36. Ernest Kolman, "Is It Possible to Prove or Disprove Mendelism by Mathematical and Statistical Methods?" *Comptes Rendus (Doklady) de l'Académie des Sciences de l'URSS* 28 (1940), no. 9: 834–838.

37. Kotkin, *Magnetic Mountain*, p. 225.

38. The tetrad model presented here is a modified version of Epstein's scheme (*After the Future*, p. 115).

39. Orwell, *Nineteen Eighty-Four*, p. 7.

40. Epstein, *After the Future*, p. 125.

41. Ibid., p. 119.

42. Ibid., p. 121.

43. Walker, "Marxism-Leninism as Discourse," pp. 179–180.

44. See Thomas S. Kuhn, *The Structure of Scientific Revolutions* (University of Chicago Press, 1962); Robert K. Merton, *The Sociology of Science* (University of Chicago Press, 1973).

45. Graham, *Science in Russia*, p. 121.

46. On the history and principal ideas of dialectical materialism, see Graham, *Science, Philosophy, and Human Behavior*, chapter 2; David Joravsky, *Soviet Marxism and Natural Science, 1917–1932* (Columbia University Press, 1961).

47. David Holloway, "Innovation in Science: The Case of Cybernetics in the Soviet Union," *Science Studies* 4 (1974), p. 308.

48. For a recent compilation of such "classical" quotations, see Konstantin Dushenko, *Slovar' sovremennykh tsitat* (Moscow: AGRAF, 1997).

49. Krementsov, *Stalinist Science*, p. 6.

50. See Alexei Kojevnikov, "Rituals of Stalinist Culture at Work: Science and the Games of Intraparty Democracy circa 1948," *Russian Review* 57 (1998), no. 1: 25–52; Kojevnikov, "President of Stalin's Academy"; Krementsov, *Stalinist Science*.

51. Quoted in Kojevnikov, "President of Stalin's Academy," p. 38.

52. Ibid.

53. Sinyavsky, *Soviet Civilization*, p. 195.

54. Thom, *Newspeak*, p. 53.

55. See Anderson, "'Look at All Those Nouns in a Row.'"

56. Quoted in Thom, *Newspeak*, p. 53.

57. On the indeterminacy of ideological translation, see Kojevnikov, "Rituals of Stalinist Culture," p. 50.

58. See, e.g., Pavel S. Aleksandrov, "O novykh techeniiakh matematicheskoi mysli, voznikshikh v sviazi s teoriei mnozhestva," *Front nauki i tekhniki* 1934, no. 3–4: 24–33.

59. Abram Deborin et al., "O bor'be na dva fronta," *Pod znamenem marksizma* 1930, no. 5, p. 147.

60. *Pod znamenem marksizma* 1930, no. 10–12, p. 17.

61. See Sheila Fitzpatrick, "The *Lady Macbeth* Affair: Shostakovich and the Soviet Puritans," in Fitzpatrick, *The Cultural Front* (Cornell University Press, 1992).

62. See Soyfer, *Lysenko and the Tragedy of Soviet Science*, p. 321, nn. 36 and 47.

63. Ibid., p. 123.

64. Quoted in ibid., p. 132.

65. Kolman, "Is It Possible to Prove or Disprove Mendelism," p. 837.

66. David Hilbert, "Naturerkennen und Logik," *Naturwissenschaften* 46 (1930), p. 959.

67. Kolman, "Is It Possible to Prove or Disprove Mendelism," p. 837.

68. Thomas Riha, ed., *Readings in Russian Civilization*, volume 3 (University of Chicago Press, 1969), p. 692.

69. See, e.g., Agniia V. Desnitskaia, "Protiv formalizma v uchenii o zvukakh rechi," *Izvestiia Akademii nauk SSSR. Otdelenie literatury i iazyka* 8 (1949), no. 4: 337–342.

70. O. A. Reutov, "K voprosu o formalizme i uproshchenchestve v teorii organicheskoi khimii," *Voprosy filosofii* 1950, no. 2: 181–194.

71. See Vucinich, *Empire of Knowledge*, pp. 220–225.

72. Quoted in Rossianov, "Editing Nature," p. 732.

73. Ermilin to the Central Committee, ca. 15 June 1948 (RGASPI, f. 17, op. 132, d. 36, ll. 14–27).

74. Eduard I. Kolchinksii, "Vzgliad iz rektorata na biologiiu v Leningradskom universitete (Interv'iu s akademikom A. D. Aleksandrovym)," in *Repressirovannaia nauka*, volume II, ed. M. Iaroshevskii (St. Petersburg: Nauka, 1994), p. 175.

75. See Aleksandr D. Aleksandrov, "Leninskaia dialektika i matematika," *Priroda* 1951, no. 1: 5–16; Aleksandrov, "Ob idealizme v matematike" (part I), *Priroda* 1951, no. 7: 3–11; Aleksandrov, "Ob idealizme v matematike" (part II), *Priroda* 1951, no. 8: 3–9.

76. Aleksandrov, "Ob idealizme v matematike" (part II), p. 8.

77. Ibid., p. 4.

78. Ibid., p. 9.

79. Leonid E. Maistrov, "Bor'ba materializma s idealizmom v teorii veroiatnostei," *Nauka i zhizn'* 1954, no. 4, p. 43.

80. Aleksei A. Liapunov, "Otzyv o dissertatsii L. E. Maistrova, 'Bor'ba materializma s idealizmom v teorii veroiatnostei.'" 5 December 1950 (ARAN, f. 1875, sdatochnaia op. 2, d. 173, ll. 5–6).

81. Tugarinov and Maistrov, "Protiv idealizma v matematicheskoi logike," p. 332.

82. Aleksandrov, "Ob idealizme v matematike" (part II), p. 9.

83. For a standard history of the Russian Formalist movement, see Victor Erlich, *Russian Formalism: History, Doctrine*, third edition (Yale University Press, 1981). See also Roman Jakobson, "An Example of Migratory Terms and Institutional Models (On the Fiftieth Anniversary of the Moscow Linguistic Circle)," in *Selected Writings*, volume II: *Word and Language* (Mouton, 1971).

84. Viktor Shklovskii, *O teorii prozy* (Moscow: Krug, 1925), p. 162.

85. Quoted in Erlich, *Russian Formalism*, pp. 76–77.

86. Quoted in ibid., p. 97.

87. Quoted in ibid., p. 100.

88. For an overview of the evolution of Jakobson's ideas, see Linda R. Waugh and Monique Monville-Burston, "Introduction: The Life, Work, and Influence of Roman Jakobson," in Roman Jakobson, *On Language*, ed. Waugh and Monville-Burston (Harvard University Press, 1990). See also the extensive bibliography in the same volume.

89. Czech weekly *ČIN* (31 October 1929), as quoted in Roman Jakobson, "Retrospect," in *Selected Writings*, volume II, p. 711.

90. Sigmund J. Sluszka, chairman of Polish American Congress, as quoted in anonymous 1950 newspaper article, "Reds Admit Role in Columbia Deal" (Jakobson papers, MIT MC72, box 38.56).

91. Desnitskaia, "Protiv formalizma," pp. 338–339.

92. Ibid., p. 342.

93. Ibid., p. 337.

94. Ibid., p. 342.

95. On the history of Marrism and the controversial role of this doctrine in Soviet linguistics, see Vladimir M. Alpatov, *Istoriia odnogo mifa: Marr i marrizm* (Moscow: Nauka, 1991); Alpatov, "Marr, Marrism, and Stalinism," *Russian Studies in History* 34 (1995), no. 2: 37–61; Mikhail V. Gorbanevskii, *V nachale bylo slovo: maloizvestnye stranitsy istorii sovetskoi lingvistiki* (Moscow: Universitet druzhby narodov, 1991); Yuri Slezkine, "N. Ia. Marr and the National Origins of Soviet Ethnogenetics," *Slavic Review* 55 (1996), no. 4: 826–862.

96. See Ivan I. Meshchaninov, "O polozhenii v lingvisticheskoi nauke," *Izvestiia Akademii nauk SSSR. Otdelenie literatury i iazyka* 1948, no. 6: 473–485; Fedot P. Filin, "O dvukh napravleniiakh v lingvistike," *Izvestiia Akademii nauk SSSR. Otdelenie literatury i iazyka* 1948, no. 6: 486–496; "O polozhenii v lingvisticheskoi nauke," *Vestnik Akademii nauk SSSR* 1948, no. 12: 71–74.

97. See Filin, "O dvukh napravleniiakh v lingvistike," p. 496.

98. Alpatov, "Marr, Marrism, and Stalinism," p. 53.

99. This strategy, which one might call "two steps forward, one step back," allowed Stalin to put the blame for the "excesses" of his own policy on low-ranking officials and to portray himself as a savior. Compare Stalin's 1930 article "Dizzy with Success," which condemned the "excesses" of forced collectivization, and his 1935 formula, "the son is not responsible for his father," announced after the completion of the large-scale systematic deportation to distant provinces of so-called *kulaks* (well-to-do peasants) and their entire families.

100. Alexander I's minister Arakcheev supervised the introduction of military-type settlements in Russia circa 1820; his name was often associated with the idea of subjecting society to military discipline.

101. There were speculations at the time that Stalin must have confused one of the Russian dialects with the Kursko-Orlovskaia military operation of World War II.

102. Gorbanevskii, *V nachale bylo slovo*, p. 120.

103. Iuz Aleshkovskii, "Ne unyvai, zimoi dadut svidan'e . . . ," *Novyi mir* 1988, no. 12, p. 121.

104. This letter, signed by graduate student Ekaterina Krasheninnikova, was actually written by her advisor, the philosopher Aleksandr Spirkin. See Aleksandr G. Spirkin, "Rovesnik Sovetskoi vlasti (Vospominaniia)," *Vestnik* 9.2 (1997), no. 14, pp. 54–56.

105. Iosif V. Stalin, "Otvet tovarishchu E. Krasheninnikovoi" (1950), in Stalin, *Sochineniia*, volume 3 [XVI], p. 156.

106. L. S. Barkhudarov and G. V. Kolshanskii, review of the American journal *Language* (1952–1953), *Voprosy iazykoznaniia* 1954, no. 5, p. 131.

107. Ivan P. Pavlov, *Lektsii po fiziologii, 1912–1913* (Moscow: AMN SSSR, 1949), p. 55.

108. Ivan P. Pavlov, "Estestvoznanie i mozg" (1909), in Pavlov, *Mozg i psikhika: Izbrannye psikhologicheskie trudy*, ed. M. Iaroshevskii (Moscow and Voronezh: MODEK, 1996), p. 77.

109. On Pavlov, see Noravard A. Grigorian, *Ivan Petrovich Pavlov* (Moscow: Nauka, 1999); *I. P. Pavlov: pro et contra,* comp. Iu. Golikov and K. Lange (St. Petersburg: RKhGI, 1999); Joravsky, *Russian Psychology*; Daniel P. Todes, "From the Machine to the Ghost Within: Pavlov's Transition from Digestive Physiology to Conditional Reflexes," *American Psychologist* 52 (1997), no. 9: 947–955; Todes, "Pavlov and the Bolsheviks," *History and Philosophy of the Life Sciences* 17 (1995): 379–418; Todes, "Pavlov's Physiology Factory," *Isis* 88 (1997), no. 2: 205–246.

110. See Todes, "Pavlov's Physiology Factory."

111. Ivan P. Pavlov, "Otvet fiziologa psikhologam" (1932), in Pavlov, *Mozg i psikhika*, pp. 182–183. For a somewhat imprecise contemporary translation, see Ivan P. Pavlov, "Reply of a Physiologist," tr. R. Lyman, *Psychological Review* 39 (1932): 126–127.

112. Quoted in Todes, "Pavlov's Physiology Factory," p. 211.

113. Pavlov, "Estestvoznanie i mozg," pp. 70–71. In his 1924 lecture series, Pavlov still used the same metaphor; see Ivan P. Pavlov, *Lektsii o rabote bol'shikh polusharii*

golovnogo mozga (Leningrad: Izdatel'stvo Akademii nauk SSSR [1927] 1949), pp. 41–42.

114. Pavlov, *Lektsii o rabote bol'shikh polusharii*, p. 43.

115. On the Central Institute of Labor, see Kendall Bailes, "Alexei Gastev and the Soviet Controversy over Taylorism, 1918–1924," *Soviet Studies* 29 (1977), no. 3: 373–394; A. V. Smetanin et al., *TsIT i ego metody NOT* (Moscow: Ekonomika, 1970); Richard Stites, *Revolutionary Dreams : Utopian Vision and Experimental Life in the Russian Revolution* (Oxford University Press, 1989), chapter 7.

116. On Bernshtein, see Oleg G. Gazenko and Iosif M. Feigenberg, "Nikolai Aleksandrovich Bernshtein (1896–1966)," in Nikolai A. Bernshtein, *Fiziologiia dvizhenii i aktivnost'*, ed. Gazenko (Moscow: Nauka, 1990); Viacheslav E. Demidov, "U istokov fiziologii aktivnosti. Nikolai Aleksandrovich Bernshtein i razvitie otechestvennykh biokiberneticheskikh issledovanii," in *Kibernetika: proshloe dlia budushchego*, ed. B. Biriukov (Moscow: Nauka, 1989); H. T. A. Whiting, ed., *Human Motor Actions: Bernstein Reassessed* (North-Holland, 1984); Loren R. Graham, *Science, Philosophy, and Human Behavior*, pp. 192–197; Alex Kozulin, *Psychology in Utopia: Toward a Social History of Soviet Psychology* (MIT Press, 1984), pp. 62–73; Irina Sirotkina, "N. A. Bernshtein: The Years Before and After the 'Pavlov Session'," *Russian Studies in History* 34 (1995), no. 2: 24–36.

117. On biomechanics, see Anson Rabinbach, *The Human Motor: Energy, Fatigue, and the Origins of Modernity* (University of California Press, 1990).

118. Nicholas Bernstein, "The Problem of the Interrelation of Co-ordination and Localization" (1935), in Bernstein, *The Co-ordination and Regulation of Movements* (Pergamon, 1967), p. 33.

119. "Ten successive repetitions of the same movement," Bernshtein argued (ibid.), "demand ten successive impulses all different from each other."

120. See excerpts from Nikolai A. Bernshtein, "Fiziologiia dvizhenii" (1934), in Bernshtein, *Ocherki po fiziologii dvizhenii i fiziologii aktivnosti* (Moscow: Meditsina, 1966), pp. 77–78.

121. See Krementsov, *Stalinist Science*, pp. 260–275. For the proceedings of the meeting, see *Nauchnaia sessiia, posviashchennaia problemam fiziologicheskogo ucheniia akademika I. P. Pavlova, 28 iiunia-4 iiulia 1950 g.: stenograficheskii otchet* (Moscow: AN SSSR, 1950).

122. A. N. Krestovnikov, "Na porochnykh pozitsiiakh (po povodu knigi prof N. A. Bernshteina 'O postroenii dvizhenii')," *Teoriia i praktika fizicheskoi kul'tury* 12 (1949), no. 5, p. 343.

123. Sirotkina, "N. A. Bernshtein," pp. 30–32.

124. Compare the Soviet definition of ideology as "a system of views and ideas within whose framework people *perceive* and *evaluate* both their relations to reality and to each other" (*The Great Soviet Encyclopaedia*, ed. A. Prokhorov, volume 10, Macmillan, 1973, p. 120). On various interpretations of the concept of ideology, see Terry Eagleton, *Ideology: An Introduction* (Verso, 1991).

125. Gerovitch, "Writing History in the Present Tense," p. 218.

126. Heller, *Cogs in the Soviet Wheel*, p. 295.

127. Sof'ia A. Ianovskaia, "Pis'mo v redaktsiiu," *Voprosy filosofii* 1950, no. 3, pp. 339–340.

Notes to Chapter 2

1. *The Social Impact of Cybernetics* , ed. C. Dechert (Simon & Schuster, 1966), pp. 74–75.

2. Warren Weaver, "Report of the Special Committee," *Science* 130 (20 November 1959), reprinted in *A Stress Analysis of a Strapless Evening Gown*, ed. R. Baker (Prentice-Hall, 1963), pp. 153–154.

3. Ibid., p. 154.

4. On the metaphorical roots of the cybernetic language, see Paul Edwards, *The Closed World*; N. Katherine Hayles, *How We Became Posthuman: Virtual Bodies in Cybernetics, Literature, and Informatics* (University of Chicago Press, 1999); Lily E. Kay, *Who Wrote the Book of Life? A History of the Genetic Code* (Stanford University Press, 2000).

5. "A Note on the Contributors," in *A Stress Analysis of a Strapless Evening Gown*, ed. Baker, p. 191.

6. Peter Galison, "The Ontology of the Enemy."

7. Andy Pickering, "Cyborg History and the WWII Regime," *Perspectives on Science* 3 (1995): 1–48.

8. Edwards, *The Closed World*.

9. Mindell, 'Datum for Its Own Annihilation,' p. 444.

10. Heims, *John von Neumann and Norbert Wiener*, pp. 208–209.

11. David F. Noble, *Forces of Production: A Social History of Industrial Automation* (Knopf/Random House, 1984), p. 71.

12. Donna J. Haraway, "A Cyborg Manifesto: Science, Technology, and Socialist-Feminism in the Late Twentieth Century," in Haraway, *Simians, Cyborgs, and Women*, p. 163. See Galison's critique of this interpretation of cybernetics in "The Ontology of the Enemy" (pp. 259–261).

13. On Wiener, see Heims, *John von Neumann and Norbert Wiener*; Pesi R. Masani, *Norbert Wiener, 1894–1964* (Birkhäuser, 1990).

14. On Kolmogorov, see David G. Kendall, "Kolmogorov: The Man and His Work," *Bulletin of the London Mathematical Society* 22 (1990): 31–47; Andrei N. Shiriaev, ed., *Kolmogorov v vospominaniiakh* (Moscow: Nauka, 1993); Vladimir M. Tikhomirov, "The Life and Work of Andrei Nikolaevich Kolmogorov," *Russian Mathematical Surveys* 43 (1988), no. 6: 1–39.

15. Vladimir M. Tikhomirov, "A. N. Kolmogorov," in *Golden Years of Moscow Mathematics*, ed. S. Zdravkovska and P. Duren (American Mathematical Society, 1993), p. 103.

16. Norbert Wiener, *I Am a Mathematician. The Later Life of a Prodigy* (Doubleday, 1956), p. 145.

17. "Kibernetika i literatura," *Literaturnaia gazeta*, 30 June 1960, p. 4.

18. See André N. Kolmogoroff, "Sur l'interpolation et extrapolation des suites stationnaires," *Comptes Rendus de l'Académie des Sciences de Paris* 208 (1939): 2043–2045; Kolmogorov, "Statsionarnye posledovatel'nosti v gil'bertovom prostranstve," *Biulleten' MGU. Matematika* 2 (1941), no. 6: 1–40; Kolmogorov, "Interpolirovanie i ekstrapolirovanie statsionarnykh sluchainykh posledovatel'nostei," *Izvestiia AN SSSR. Matematika* 5 (1941): 3–14.

19. Masani, *Norbert Wiener*, p. 194.

20. Not until 1949 was Wiener able to publish his results. See Mindell, 'Datum for Its Own Annihilation,' pp. 436–437.

21. Quoted in Masani, *Norbert Wiener*, p. 193.

22. Referring to the 1949 publication of Wiener's book *Extrapolation, Interpolation, and Smoothing of Stationary Time Series*, Peter Whittle has concluded: "Kolmogorov and Wiener are generally given joint credit for the development of the prediction theory of stationary processes. This surely constitutes insufficient recognition of Kolmogorov's clear ten-year priority." (Whittle, "Kolmogorov's Contributions to the Theory of Stationary Processes," *Bulletin of the London Mathematical Society* 22, 1990, p. 84) See also Masani, *Norbert Wiener*, pp. 193–195. As stated above, Wiener's report was already in restricted circulation in 1942, which still gives Kolmogorov a lead.

23. Andrei N. Kolmogoroff, "On a New Confirmation of Mendel's Laws," *Comptes Rendus (Doklady) de l'Académie des Sciences de l'URSS* 27 (1940), no. 1, p. 37.

24. Trofim D. Lysenko, "In Response to an Article by A. N. Kolmogoroff," *Comptes Rendus (Doklady) de l'Académie des Sciences de l'URSS* 28 (1940), no. 9, pp. 833, 832.

25. Ernest Kolman, "Is It Possible to Prove or Disprove Mendelism by Mathematical and Statistical Methods?" *Comptes Rendus (Doklady) de l'Académie des Sciences de l'URSS* 28 (1940), no. 9, p. 837.

26. See Kolmogorov's extended footnote in Julii J. Kerkis and Aleksei A. Liapounoff, "Segregation in Hybrids," *Comptes Rendus (Doklady) de l'Académie des Sciences de l'URSS* 31 (1941), no. 1: 47–50.

27. Vladimir Arnol'd, one of Kolmogorov's most talented disciples, later recalled: "In 1959 [Kolmogorov] asked me to omit from the paper on self-maps of the circle the section on applications to heartbeats, adding 'That is not one of the classical problems one ought to work on.' The application to the theory of heartbeats was published by L. Glass 25 years later, while I had to concentrate my efforts on the celestial-mechanical applications of the same theory"; quoted in Paul M. B. Vytanyi, "Andrei Nikolaevich Kolmogorov [obituary]," *CWI Quarterly* 1 (1988): 3–18.

28. Heims, *John von Neumann and Norbert Wiener*, p. 193.

29. See *Trudy Matematicheskogo instituta im. V. A. Steklova* 12 (1945).

30. O. V. Golubev et al., "Problems of Control and Effectiveness Evaluation in the Development of the Soviet Antimissile Defense System. 1. Experimental Proving Ground System (System A)," *Journal of Computer and Systems Sciences International* 32 (1994), no. 2, p. 82.

31. Mindell, 'Datum for Its Own Annihilation,' p. 439.

32. Wiener, *Cybernetics*, p. 6.

33. On Wiener's work on the anti-aircraft predictor, see Galison, "The Ontology of the Enemy"; Pesi Masani and R. S. Phillips, "Antiaircraft Fire-Control and the Emergence of Cybernetics," in Norbert Wiener, *Collected Works with Commentaries*, volume IV, ed. P. Masani (MIT Press, 1985); Mindell, 'Datum for Its Own Annihilation,' pp. 433–445.

34. Wiener, *Cybernetics*, p. 8.

35. Ibid., p. 7.

36. Arturo Rosenblueth, Norbert Wiener, and Julian Bigelow, "Behavior, Purpose and Teleology," *Philosophy of Science* 10 (1943): 18–24.

37. Ibid., p. 22.

38. Wiener, *Cybernetics*, p. 128.

39. Ibid., p. 113.

40. Norbert Wiener, *The Human Use of Human Beings: Cybernetics and Society* (Avon Books, [1954] 1967), p. 26.

41. Erwin Schrödinger, *What Is Life? The Physical Aspect of the Living Cell* (Cambridge University Press, 1945), pp. 69, 74.

42. See Walter Moore, *Schrödinger: Life and Thought* (Cambridge University Press, 1989), pp. 394–404.

43. Schrödinger, *What Is Life?*, p. 1.

44. Ibid., p. 19.

45. Ibid., p. 82.

46. Ibid., p. 34.

47. Max F. Perutz, "Erwin Schrödinger's *What Is Life?* and Molecular Biology," in *Schrödinger*, ed. C. Kilmister (Cambridge University Press, 1987), p. 243.

48. Evelyn Fox Keller, "Physics and the Emergence of Molecular Biology: A History of Cognitive and Political Synergy," *Journal of the History of Biology* 23 (1990), no. 3: 389–409. See also Edward J. Yoxen, "Where Does Schrödinger's 'What Is Life?' Belong in the History of Molecular Biology?" *History of Science* 62 (1979): 17–52.

49. See Kay, *Who Wrote the Book of Life?*, pp. 59–66.

50. Schrödinger, *What Is Life?*, p. 79.

51. Wiener, *Cybernetics*, p. 8.

52. Quoted in Mindell, 'Datum for Its Own Annihilation,' p. 489.

53. Quoted in ibid., p. 488.

54. Quoted in ibid., p. 220.

55. Quoted in ibid., p. 221.

56. Quoted in ibid., p. 220.

57. Quoted in ibid., p. 224.

58. Ibid., p. 218.

59. Andrew Hodges, *Alan Turing: The Enigma* (Simon & Schuster, 1983), pp. 245–269.

60. Claude Shannon, telephone interview by David Kahn, 27 November 1961, quoted in David Kahn, *The Code Breakers* (Macmillan, 1967), p. 744.

61. On the emergence of information theory, see William Aspray, "The Scientific Conceptualization of Information: A Survey," *Annals of the History of Computing* 7, no. 2 (April 1985): 117–140; Edwards, *The Closed World*, pp. 199–205; Kay, *Who Wrote the Book of Life?*, pp. 91–102; Mindell, 'Datum for Its Own Annihilation,' chapters 9 and 10.

62. Compare Shannon's description of "the uncertainty (or entropy) of the joint event *x*, *y*" and his explanation of conditional entropy as a measure of "how uncertain we are of *y* on the average when we know *x*" (Claude E. Shannon and Warren Weaver, *The Mathematical Theory of Communication*, University of Illinois Press, 1949, p. 52).

63. See Claude E. Shannon, "A Mathematical Theory of Communication," *Bell System Technical Journal* 27 (1948), no. 3: 379–423, 623–656; Shannon, "Communication Theory of Secrecy Systems," *Bell System Technical Journal* 28 (1949), no. 4: 656–715.

64. Shannon and Weaver, *The Mathematical Theory of Communication*, pp. 33–34.

65. Ibid., p. 44.

66. Analog computers represent the mathematical problem to be solved by a physical process. The problem variables are represented by continuously variable physical parameters such as mechanical motion, fluid pressure, or electrical potential; answers are obtained by measuring the output variables. Digital computers represent the problem variables in discrete, usually binary, form, as numbers stored in computer memory, and solve problems numerically via a sequence of mathematical and logical operations.

67. M. D. Fagen, ed., *A History of Engineering and Science in the Bell System*, volume 2 (Bell Telephone Laboratories, 1978), p. 165.

68. Mindell, 'Datum for Its Own Annihilation,' p. 448.

69. Wiener, *Cybernetics*, p. 4.

70. Alan M. Turing, "On Computable Numbers, with an Application to the Entscheidungsproblem," *Proceedings of the London Mathematical Society*, series 2, 42 (1936–37), reprinted in *The Undecidable*, ed. M. Davis (Raven, 1965), p. 136.

71. Ibid., p. 117.

72. Hodges, *Alan Turing*, p. 251.

73. Wiener, *Cybernetics*, pp. 124–125.

74. On McCulloch, see Heims, *Constructing a Social Science for Postwar America*, chapter 3.

75. Warren S. McCulloch, "Machines That Think and Want" (1950), in McCulloch, *Embodiments of Mind* (MIT Press, 1965), p. 307.

76. Warren S. McCulloch, "What Is a Number, that a Man May Know It, and a Man, that He May Know a Number?" (1961), in McCulloch, *Embodiments of Mind*, p. 1 (emphasis added).

77. Ibid., pp. 8–9.

78. Wiener, *Cybernetics*, p. 42. On Rashevsky, see Robert Rosen, "Nicolas Rashevsky, 1899–1972," in *Progress in Theoretical Biology*, volume 2, ed. R. Rosen and F. Snell (Academic Press, 1972).

79. Warren S. McCulloch, "A Historical Introduction to the Postulational Foundations of Experimental Epistemology" (1964), in McCulloch, *Embodiments of Mind*, p. 369.

80. McCulloch made this remark during the discussion of von Neumann's paper "The General and Logical Theory of Automata" at the Hixon Symposium (Pasadena, California, 20 September 1948). See William Aspray and Arthur Burks, eds., *Papers of John von Neumann on Computing and Computer Theory* (MIT Press and Tomash, 1987), p. 422.

81. Warren S. McCulloch and Walter H. Pitts, "A Logical Calculus of the Ideas Immanent in Nervous Activity" (1943), in McCulloch, *Embodiments of Mind*, p. 19.

82. See McCulloch, "A Historical Introduction."

83. McCulloch and Pitts, "A Logical Calculus," p. 38.

84. Ibid., p. 37.

85. Ibid., p. 35.

86. Ibid.

87. Aspray and Burks, *Papers of John von Neumann*, p. 423.

88. McCulloch, "What Is a Number," p. 2.

89. McCulloch, "A Historical Introduction," p. 367.

90. McCulloch, "What Is a Number," p. 10.

91. Wiener, *Cybernetics*, p. 14.

92. For a Plutarch-style parallel biography of the two men, see Heims, *John von Neumann and Norbert Wiener*. On von Neumann, see also William Aspray, *John von Neumann and the Origins of Modern Computing* (MIT Press, 1990).

93. Heims, *John von Neumann and Norbert Wiener*, p. 209.

94. Aspray, *John von Neumann*, p. 240.

95. John von Neumann, "Theory and Organization of Complicated Automata" (1949), in Aspray and Burks, *Papers of John von Neumann*, p. 449.

96. John von Neumann, "First Draft of a Report on the EDVAC" (1945), in Aspray and Burks, *Papers of John von Neumann*, p. 24.

97. John von Neumann, "The General and Logical Theory of Automata" (1948), in Aspray and Burks, *Papers of John von Neumann*, p. 400.

98. von Neumann, "Theory and Organization of Complicated Automata," p. 448.

99. Ibid., p. 471–472.

100. John von Neumann, *The Computer and the Brain* (Yale University Press, 1958), p. 1.

101. Ibid., p. 75.

102. John von Neumann, "Probabilistic Logics and the Synthesis of Reliable Organisms from Unreliable Components" (1952), in Aspray and Burks, *Papers of John von Neumann*, p. 554.

103. von Neumann, "The General and Logical Theory of Automata," p. 428.

104. Wiener, *Cybernetics*, p. 11.

105. Ibid.

106. See Heims, *Constructing a Social Science*.

107. Wiener, *Cybernetics*, p. 14.

108. Ibid., p. 15.

109. Ibid.

110. Chris C. Bissell, "Spreading the Word: Aspects of the Evolution of the Language of the Measurement of Control," *Measurement and Control* 27 (June 1994), p. 154.

111. See, e.g., Richard Taylor, "Comments on a Mechanistic Conception of Purposefulness," *Philosophy of Science* 17 (1950): 310–317.

112. Arturo Rosenblueth and Norbert Wiener, "Purposeful and Non-Purposeful Behavior," *Philosophy of Science* 17 (1950), p. 326.

113. Wiener, *The Human Use of Human Beings*, p. 25 (emphasis added).

114. See Heims, *Constructing a Social Science*, pp. 285–286.

115. In a letter to Wiener, Shannon acknowledged that they had "somewhat complimentary views of information": "I consider how much information is *produced* when a choice is made from a set—the larger the set the *more* information. You consider the larger uncertainty in the case of a larger set to mean less knowledge of the situation and hence *less* information. The difference in viewpoint is partially a mathematical pun. We would obtain the same numerical answers in any particular question." (Shannon to Wiener, 13 October 1948, Wiener Papers, MIT MC22, box 2.85) On the difference between Shannon's and Wiener's definitions of information, see also Peter Elias, "Predictive Coding," *IRE Transactions on Information Theory* IT-1 (1955), p. 21.

116. Wiener, *Cybernetics*, p. 11.

117. Wiener, *The Human Use of Human Beings*, p. 129.

118. Wiener, *Cybernetics*, p. 97.

119. Wiener, *The Human Use of Human Beings*, pp. 24–25.

120. Wiener, *Cybernetics*, p. 120.

121. Ibid., p. 123.

122. Ibid., p. 130.

123. Peter Galison calls the intermediate cultural domain where different groups of physicists can locally coordinate their actions and beliefs despite the global differences in their symbolic and cultural systems a "trading zone" (*Image and Logic*, University of Chicago Press, 1997, chapter 9).

124. Compare Galison's description of the attempts to create "a stable pidgin language, designed to mediate between experimentalist and theorist" ("Trading Zone: Coordinating Action and Belief," in *The Science Studies Reader*, ed. M. Biagioli, Routledge, 1999, pp. 155–156).

125. Heims, *Constructing a Social Science*, p. 28.

126. Wiener, *Cybernetics*, p. 44.

127. Wiener, *The Human Use of Human Beings*, p. 46.

128. Ibid., pp. 46–47.

129. Wiener, *Cybernetics*, p. 132.

130. Quoted in Heims, *Constructing a Social Science*, p. 29.

131. Quoted in Mindell, 'Datum for Its Own Annihilation,' p. 220.

132. Warren Weaver, "Recent Contributions to the Mathematical Theory of Communication," in Shannon and Weaver, *The Mathematical Theory of Communication,* pp. 1, 24.

133. Ibid., p. 26.

134. Ibid., p. 28.

135. See Kay, *Who Wrote the Book of Life?*, pp. 297–315.

136. Jakobson to Wiener, 24 February 1949 (Wiener Papers, MIT MC22, box 6.92).

137. Roman Jakobson, "Linguistics and Communication Theory" (1960), in Jakobson, *On Language*, ed. Waugh and Monville-Burston, p. 494.

138. Jakobson, "Retrospect," in Jakobson, *Selected Writings*, volume II: *Word and Language* (Mouton, 1971), p. 718.

139. Adapted from Roman Jakobson, "Linguistics and Poetics" (1960), in Jakobson, *Language in Literature*, ed. K. Pomorska and S. Rudy (Belknap, 1987), pp. 66–71.

140. Adapted from Jakobson, "Linguistics and Poetics," p. 71.

141. Jakobson, "Linguistics and Communication Theory," p. 497.

142. Wiener, *The Human Use of Human Beings*, p. 255.

143. Bowker, "How to Be Universal," p. 116.

144. Wiener, *Cybernetics*, p. 14.

145. Ibid., p. 26.

146. Kay, *Who Wrote the Book of Life?*, p. 83.

147. Evelyn Fox Keller, *Refiguring Life: Metaphors of Twentieth-Century Biology* (Columbia University Press, 1995), p. 108.

148. von Neumann, "The General and Logical Theory of Automata," pp. 412–413.

149. Günther Palm, "Warren McCulloch and Walter Pitts: A Logical Calculus of the Ideas Immanent in Nervous Activity," in *Brain Theory*, ed. G. Palm and A. Aertsen (Springer-Verlag, 1986), p. 230.

150. McCulloch, "What Is a Number," p. 9.

151. von Neumann, "Theory and Organization of Complicated Automata," p. 446.

152. John F. Young, as quoted in Murray Eden, "Cybernetics," in *The Study of Information*, ed. F. Machlup and U. Mansfield (Wiley, 1983), p. 417.

153. See Edmund C. Berkeley, *Giant Brains, or Machines That Think* (Wiley, 1949); Serge Fliegers, "Will Machines Replace the Human Brain?" *American Monthly* 76 (1953), no. 349: 53–61; John E. Pfeiffer, "Brains and Calculating Machines," *American Scholar* 19 (1949–50), no. 1: 21–30.

154. See John G. Kemeny, "Man Viewed as a Machine," *Scientific American* 192 (April 1955): 58–67.

155. Frank H. George, "Could Machines Be Made to Think?" *Philosophy* 31 (1956), no. 118, p. 252.

156. See Karl W. Deutsch, *The Nerves of Government: Models of Political Communication and Control* (Free Press of Glencoe, 1963).

157. See *Automatic Control* (Simon & Schuster, 1955).

158. See Stafford Beer, *Cybernetics and Management* (Wiley, 1959) and *Decision and Control: The Meaning of Operational Research and Management Cybernetics* (Wiley, 1966).

159. See Sydney M. Dancoff and Henry Quastler, "The Information Content and Error Rate of Living Things," in *Essays on the Information Theory in Biology*, ed. Quastler (University of Illinois Press, 1953).

160. Kay, *Who Wrote the Book of Life?*, p. 41.

161. Quoted in ibid., p. 126.

162. Ibid.

163. Bowker, "How to Be Universal," p. 117.

164. Shannon and Weaver, *The Mathematical Theory of Communication,* p. 31.

165. Claude E. Shannon, "The Bandwagon," *IEEE Transactions Information Theory*, volume 2 (March 1956), reprinted in Claude Elwood Shannon, *Collected Papers*, ed. N. Sloane and A. Wyner (IEEE Press, 1993), p. 462.

166. M. Mitchell Waldrop, "Claude Shannon: Reluctant Father of the Digital Age," *Technology Review*, July-August 2001: 64–71.

167. Norbert Wiener and Donald Campbell, "Automatization" (1954), in Wiener, *Collected Works*, volume IV, p. 683.

168. See Hayles, *How We Became Posthuman*, chapter 4.

169. Wiener, *Cybernetics*, p. 27.

170. Ibid., p. 28.

171. Norbert Wiener, "The Machine as Threat and Promise" (1953), in Wiener, *Collected Works*, volume IV, p. 677.

172. Wiener, *Cybernetics*, p. 27.

173. Ibid., p. 28.

174. Ibid., p. 159.

175. Ibid., p. 160.

176. Ibid., p. 164.

177. Quoted in Wiener, *The Human Use of Human Beings*, pp. 245, 247.

178. Ibid., pp. 249–250.

179. See Heims, *Constructing a Social Science*, pp. 181–184.

180. See Norbert Wiener, "A Scientist Rebels" (1947), in Wiener, *Collected Works*, volume IV, p. 748. On the links between cybernetics and military research in the West, see Edwards, *The Closed World*; Agatha C. Hughes and Thomas P. Hughes, eds., *Systems, Experts, and Computers* (MIT Press, 2000).

181. "Information and entropy are not conserved," wrote Wiener, "and are equally unsuited to being commodities" (*The Human Use of Human Beings*, p. 159).

Notes to Chapter 3

1. Il'ia B. Novik, "Normal'naia lzhnauka," *Voprosy istorii estestvoznaniia i tekhniki* 1990, no. 4, p. 4.

2. See Wiener, *Cybernetics*, pp. 11, 59, 127.

3. Andrei A. Markov, "Primer statisticheskogo issledovaniia nad tekstom 'Evgeniia Onegina' illiustriruiushchii sviaz' ispytanii v tsep'," *Izvestiia Imperatorskoi Akademii Nauk* 283, seriia 6, volume 7 (1913): 153–162.

4. Claude E. Shannon and Warren Weaver, *The Mathematical Theory of Communication* (University of Illinois Press, 1949), p. 45.

5. See Graham, *Science in Russia and the Soviet Union*, pp. 255–256. On the history of Magnitogorsk, see Kotkin, *Magnetic Mountain*.

6. See I. A. Apokin and A. Z. Chapovskii, "The Origins of the First Soviet Scientific Center for Automation," *History and Technology* 8 (1992): 133–138.

7. Professor P. P. Troianskii, who led the project "Thinking and Automation," proposed to build a mechanical device for a word-by-word translation from one language into another as early as 1933. See Dmitrii Iu. Panov, Aleksei A. Liapunov, and I. S. Mukhin, "Avtomatizatsiia perevoda s odnogo iazyka na drugoi," in *Sessiia Akademii nauk SSSR po nauchnym problemam avtomatizatsii proizvodstva, 15–20 oktiabria 1956 g.: Plenarnye zasedaniia*, ed. V. Trapeznikov (Moscow: AN SSSR, 1957), p. 193. For the proceedings of this conference, see ARAN, f. 444, op. 2.

8. Quoted in I. A. Apokin and A. Z. Chapovskii, "Pervyi v mire nauchnyi tsentr po avtomatike," in *Kibernetika*, ed. B. Biriukov (Moscow: Nauka, 1989), p. 95.

9. See Chris C. Bissell, "A. A. Andronov and the Development of Soviet Control Engineering," *IEEE Control Systems Magazine* 18 (1998), no. 1: 56–62; Bissell, "Control Engineering in the former USSR: Some Ideological Aspects of the Early Years," *IEEE Control Systems Magazine* 19 (1999), no. 1: 111–117.

10. See Aleksandr A. Pechenkin, "Ot avtokolebanii k samoorganizatsii: formirovanie sinergeticheskikh idei v teorii nelineinykh kolebanii," in *Kontseptsii samoorganizatsii v istoricheskoi retrospektive*, ed. Pechenkin (Moscow: Nauka, 1994), pp. 104–124; Pechenkin, "The Concept of Self-Oscillations and the Rise of Synergetics Ideas in the Theory of Non-Linear Oscillations," *Studies in the History and Philosophy of Modern Physics* (forthcoming).

11. See the supplementary chapter 12, "Brain Waves and Self-Organizing Systems," in the second edition of Wiener's *Cybernetics* (1961).

12. Andronov to Aizerman, 2 August 1949 (ARAN, f. 1938, op. 1, d. 207, l. 107).

13. Andronov to Bruk, April 1950 (ARAN, f. 1938, op. 1, d. 213, l. 11).

14. Modest G. Gaaze-Rapoport, "O stanovlenii kibernetiki v SSSR," in *Ocherki istorii informatiki*, ed. Pospelov and Fet, p. 251.

15. Petr P. Lazarev, "Biofizika v Rossii i v SSSR," in *Biofizika*, ed. P. Lazarev and P. Pavlov (Moskovskoe obshchestvo ispytatelei prirody, 1940), p. 24.

16. A. V. Khramoi, "K istorii razvitiia kibernetiki," in *Filosofskie voprosy kibernetiki*, ed. V. Il'in et al. (Moscow: Izdatel'stvo sotsial'no-ekonomicheskoi literatury, 1961), pp. 199–200. On Lazarev, see Aleksei A. Liapunov, "Pamiati P. P. Lazareva," in *Ocherki istorii informatiki*, ed. Pospelov and Fet.

17. Nikolai A. Bernshtein, "Fiziologiia dvizhenii" (1934), in Bernshtein, *Ocherki po fiziologii dvizhenii i fiziologii aktivnosti* (Moscow: Meditsina, 1966), pp. 77–78.

18. Alex Kozulin, *Psychology in Utopia: Toward a Social History of Soviet Psychology* (MIT Press, 1984), p. 65.

19. Norbert Wiener, *The Human Use of Human Beings: Cybernetics and Society* (Avon Books, [1954] 1967), p. 93.

20. On Anokhin, see N. S. Dvortsina and V. A. Makarov, *Petr Kuz'mich Anokhin: Materialy k biobibliografii* (Moscow: Nauka, 1987); Graham, *Science, Philosophy, and Human Behavior in the Soviet Union*, pp. 200–211; Pavel V. Simonov, ed., *Petr Kuz'mich Anokhin: Vospominaniia sovremennikov, publitsistika* (Moscow: Nauka, 1990).

21. See M. B. Turov, "Vopreki zdravomu smyslu," *Nauka i zhizn'* 1954, no. 7: 45–46.

22. Bernard E. Bykhovskii, "Mekhanisty—prisluzhniki imperializma," *Nauka i zhizn'* 1953, no. 2, p. 44.

23. Agniia V. Desnitskaia, "Protiv formalizma v uchenii o zvukakh rechi," *Izvestiia Akademii nauk SSSR. Otdelenie literatury i iazyka* 8 (1949), no. 4, p. 337.

24. O. Leshka, "K voprosu o strukturalizme (Dve kontseptsii grammatiki v Prazhskom lingvisticheskom kruzhke)," *Voprosy iazykoznaniia* 1953, no. 5, p. 90.

25. L. S. Barkhudarov and G. V. Kolshanskii, Review of the American journal *Language* (1952–1953), *Voprosy iazykoznaniia* 1954, no. 5, p. 131.

26. See Gaaze-Rapoport, “O stanovlenii kibernetiki v SSSR,” p. 233.

27. Dmitrii A. Pospelov, *Fantaziia ili nauka: na puti k iskusstvennomu intellektu* (Moscow: Nauka, 1982), p. 75.

28. See, e.g., Aleksandr A. Maksimov, “Klassovaia bor’ba v sovremennom estestvoznanii,” *Front nauki i tekhniki* 1932, no. 9, p. 25; Maksimov, “Rassadnik idealizma v fizike,” *Bol’shevik* 1938, no. 7: 91–98.

29. Oparin mentioned this event in his speech at the meeting of the Presidium of the Soviet Academy of Sciences on 26 August 1948 (ARAN, f. 2, op. 3a, d. 95, ll. 155–156).

30. Erwin Schrödinger, *What Is Life? The Physical Aspect of the Living Cell* (Cambridge University Press, 1945), p. 88.

31. *The Situation in Biological Science. Proceedings of the Lenin Academy of Agricultural Sciences of the USSR, Session: July 31—August 7, 1948* (Moscow: Foreign Languages Publishing House, 1949), p. 24.

32. Ibid., p. 20.

33. See Kirill Rossianov, “Editing Nature: Joseph Stalin and the ‘New’ Soviet Biology,” *Isis* 84 (1993), no. 4: 728–745.

34. Quoted in Anatolii S. Sonin, *“Fizicheskii idealizm”: Istoriia odnoi ideologicheskoi kampanii* (Moscow: Fizmatlit, 1994), p. 115.

35. Ernest Kol’man, “Kuda vedet fizikov sub’ektivizm?” *Voprosy filosofii* 1953, no. 6, p. 174.

36. Dmitrii M. Troshin, “V plenu sub’ektivizma,” *Priroda* 1953, no. 9, p. 44.

37. Arkadii K. Timiriazev, as quoted in Sonin, “Fizicheskii idealizm”, p. 101.

38. On Timoféeff-Ressovsky, see Diane B. Paul and Costas B. Krimbas, “Nikolai V. Timoféeff-Ressovsky,” *Scientific American* 266 (1992), no. 2: 86–92; Nikolai V. Timofeev-Resovskii, *Vospominaniia: Istorii, rasskazannye im samim, s pis’mami, fotografiiami i dokumentami* (Moscow: Soglasie, 2000); Nikolai N. Vorontsov, ed., *Nikolai Vladimirovich Timofeev-Resovskii: Ocherki, vospominaniia, materialy* (Moscow: Nauka, 1993).

39. Sir Frederic Bartlett, *Thinking: An Experimental and Social Study* (Basic Books, 1958), p. 139.

40. Ibid., p. 144.

41. Frederic C. Bartlett, *Remembering: A Study in Experimental and Social Psychology* (Cambridge University Press, 1932), p. 168.

42. Wiener, *Cybernetics*, p. 23.

43. Evgenii S. Gromov, *Stalin: Vlast’ i iskusstvo* (Moscow: Respublika, 1998), p. 395.

44. See, e.g., Alexander Vucinich, *Empire of Knowledge: The Academy of Sciences of the USSR (1917–1970)* (University of California Press, 1984), chapter 4.

45. Nikolai Krementsov, *Stalinist Science* (Princeton University Press, 1997), pp. 5–6.

46. Compare the orthodox Pavlovians' assault on the "deviations from the Pavlov teaching," aimed chiefly at Leon Orbeli, Pavlov's influential successor. See ibid., pp. 268–274.

47. Aleksandr A. Pechenkin, "Antiresonansnaia kampaniia v kvantovoi khimii (1950–1951 gg.)," *Filosofskie issledovaniia* 1993, no. 4, p. 373. On the "anti-resonance campaign," see also Graham, *Science, Philosophy, and Human Behavior*, pp. 294–319; Pechenkin, "Antiresonansnaia kampaniia 1949–1951 gg.," in *Metafizika i ideologiia v istorii estestvoznaiia*, ed. Pechenkin (Moscow: Nauka, 1994).

48. See Alexei Kojevnikov, "Rituals of Stalinist Culture at Work: Science and the Games of Intraparty Democracy Circa 1948," *Russian Review* 57 (1998), no. 1: 25–52. On the role of formal rituals in Soviet political culture, see J. Arch Getty, "Samokritika Rituals in the Stalinist Central Committee, 1933–38," *Russian Review* 58 (1999), no. 1: 49–70.

49. Krementsov, *Stalinist Science*, p. 194.

50. Ibid., p. 215.

51. Boris Agapov, "Mark III, kal'kuliator," *Literaturnaia gazeta*, 4 May 1950: 2–3.

52. Mikhail G. Iaroshevskii, "Semanticheskii idealizm—filosofiia imperialisticheskoi reaktsii," in *Protiv filosofstvuiushchikh oruzhenostsev amerikano-angliiskogo imperializma*, ed. T. Oizerman and P. Trofimov (Moscow: AN SSSR, 1951), p. 100.

53. Mikhail Iaroshevskii, "Kibernetika—'nauka' mrakobesov," *Literaturnaia gazeta*, 5 April 1952, p. 4.

54. See Bernard E. Bykhovskii, "Kibernetika—amerikanskaia lzhenauka," *Priroda* 1952, no. 7: 125–127; Bykhovskii, "Nauka sovremennykh rabovladel'tsev," *Nauka i zhizn'* 1953, no. 6: 42–44; Teodor K. Gladkov, "Kibernetika—psevdonauka o mashinakh, zhivotnykh, cheloveke i obshchestve," *Vestnik Moskovskogo universiteta* 1955, no. 1: 57–67.

55. "Kibernetika," in *Kratkii filosofskii slovar'*, ed. M. Rozental' and P. Iudin (Moscow: Gospolitizdat, 1954), p. 236.

56. See R. David Gillespie, "The Politics of Cybernetics in the Soviet Union," in *Scientists and Public Affairs*, ed. A. Teich (MIT Press, 1974); Lee Kerschner, "Cybernetics: Key to the Future?" *Problems of Communism* 14 (November-December 1965): 56–66.

57. See "Plan meropriiatii po usileniiu antiamerikanskoi propagandy na blizhaishee vremia," 1949 (RGASPI, f. 17, op. 132, d. 224, ll. 48–52). See also D. G. Nadzhafov, "Antiamerikanskie propagandistskie pristrastiia stalinskogo rukovodstva," in *Stalinskoe desiatiletie kholodnoi voiny: fakty i gipotezy*, ed. Gaiduk et al.

58. Mark Kuchment, "Bridging the Two Cultures: The Emergence of Scientific Prose," in *Science and the Soviet Social Order*, ed. L. Graham (Harvard University Press, 1990), p. 331.

59. Agapov, "Mark III, kal'kuliator," p. 3.

60. Gelii N. Povarov, interview with S. Gerovitch, Moscow, 17 July 1996.

61. Iosif V. Stalin, "Otvet tovarishchu E. Krasheninnikovoi" (1950), in Stalin, *Sochineniia*, volume 3 [XIV], p. 154.

62. Chesnokov and Makhov to Suslov, 2 September 1952 (RGASPI, f. 17, op. 133, d. 285, l. 88).

63. Iaroshevskii, "Semanticheskii idealizm," p. 100.

64. See Petr K. Anokhin, "Zamechaniia po povodu retsenzii E. A. Shkabara i L. N. Dashevskogo na stat'iu o 'kibernetike'" (n.d.) (Rossiiskii Gosudarstvennyi arkhiv literatury i iskusstva, Moscow, f. 634, op. 3, d. 206, ll. 139–140). Shkabara and Dashevskii's article, unfortunately, did not survive in the *Literaturnaia gazeta* archive.

65. Ibid., l. 140.

66. Iaroshevskii, "Kibernetika—'nauka' mrakobesov," p. 4.

67. In 1938, during the Great Purges, Iaroshevskii was arrested on a trumped-up charge and released a year later without trial; the charges were officially dismissed only in 1991. See S. A. Kaliadina, "Fragmenty 'Dela leningradskoi studencheskoi terroristicheskoi organizatsii," in *Repressirovannaia nauka*, volume II, ed. M. Iaroshevskii (St. Petersburg, 1994).

68. See "Reshenie zakrytogo partiinogo sobraniia Instituta filosofii," 21 December 1950 (RGASPI, f. 17, op. 133, d. 8, l. 41).

69. Mikhail G. Iaroshevskii, interview with S. Gerovitch, Moscow, 2 August 1994.

70. "Otchetnyi doklad partiinogo biuro Instituta filosofii," July 1952 (RGASPI, f. 17, op. 133, d. 286, l. 157).

71. Iaroshevskii, "Kibernetika—'nauka' mrakobesov," p. 4.

72. Iaroshevskii, interview with S. Gerovitch.

73. Chesnokov and Makhov to Suslov, 2 September 1952 (RGASPI, f. 17, op. 133, d. 285, l. 88).

74. Chesnokov to Suslov, 27 March 1953 (RGASPI, f. 17, op. 133, d. 285, l. 93).

75. "Postanovlenie Uchenogo soveta Instituta filosofii," 27 May 1952 (ARAN, f. 1922, op. 1, d. 538, l. 9). See also "Kratkii obzor deiatel'nosti zhurnala 'Voprosy filosofii,'" 12 September 1953 (ARAN, f. 499, op. 2, d. 24, ll. 15–42).

76. "Otchet o rabote sektora kritiki sovremennoi burzhuaznoi filosofii i sotsiologii Instituta filosofii," 19 December 1953 (ARAN, f. 499, op. 2, d. 22, l. 14).

77. Ibid., l. 5. By "phenomenalism," Soviet experts in bourgeois philosophy apparently meant phenomenology.

78. "Plan uchebnogo posobiia 'Burzhuaznaia filosofiia i sotsiologiia epokhi imperializma,'" 1955 (ARAN, f. 1922, op. 1, d. 726, l. 115).

79. Stenogramma soveshchaniia po koordinatsii, 9 December 1953 (ARAN, f. 1922, op. 1, d. 605, ll. 2–3, 12).

80. Materialist (pseudonym), "Whom Does Cybernetics Serve?" (1953), *Soviet Cybernetics Review* 4 (1974), no. 2, pp. 35, 37.

81. Ibid., p. 43.

82. Ibid., p. 44.

83. Dashevskii to Liapunov (n.d.), in collection of Liapunov's personal papers in possession of his daughter, Natal'ia Liapunova (hereafter cited as Liapunov papers).

84. See Arnost Kolman, "The Adventure of Cybernetics in the Soviet Union," *Minerva* 3 (1978), p. 422.

85. Iu. Klemanov, "'Kibernetika' mozga," *Meditsinskii rabotnik*, 25 July 1952, p. 4.

86. "Otchet o deiatel'nosti Akademii nauk SSSR v 1956 g.," 1956 (RGANI, f. 5, op. 35, d. 30, l. 148ob).

87. Bykhovskii, "Nauka sovremennykh rabovladel'tsev," p. 44.

88. Wiener, Cybernetics, p. 132; Gladkov, "Kibernetika—psevdonauka," p. 64.

89. Nikolai V. Medvedev, *Marksistsko-leninskaia teoriia otrazheniia i uchenie I. P. Pavlova o vysshei nervnoi deiatel'nosti* (Moscow: Gospolitizdat, 1954), pp. 105–106.

90. Bykhovskii, "Kibernetika—amerikanskaia lzhenauka," p. 126.

91. On the Pavlovian physiological school, see Joravsky, *Russian Psychology*; Daniel P. Todes, "From the Machine to the Ghost Within: Pavlov's Transition from Digestive Physiology to Conditional Reflexes," *American Psychologist* 52 (1997), no. 9: 947–955; Todes, "Pavlov's Physiology Factory," *Isis* 88 (1997), no. 2: 205–246.

92. Materialist, "Whom Does Cybernetics Serve?" p. 36.

93. Graham, *Science, Philosophy, and Human Behavior*, p. 479.

94. Bykhovskii, "Kibernetika—amerikanskaia lzhenauka," p. 127.

95. Wiener, *Cybernetics*, p. 28.

96. Materialist, "Whom Does Cybernetics Serve?" p. 44.

97. Ibid., p. 37.

98. Ibid. ; Gladkov, "Kibernetika—psevdonauka," p. 64.

99. Materialist, "Whom Does Cybernetics Serve?" p. 32; Klemanov, "'Kibernetika' mozga," p. 4.

100. Wiener, *Cybernetics*, p. 164.

101. Materialist, "Whom Does Cybernetics Serve?" p. 42.

102. Gladkov, "Kibernetika—psevdonauka," p. 64.

103. "Kibernetika," p. 236.

104. See Norbert Wiener, "A Scientist Rebels" (1947), in Wiener, *Collected Works with Commentaries*, volume IV, ed. Masani, p. 748.

105. Iurii Zhdanov, "Vo mgle protivorechii," *Voprosy filosofii* 1993, no. 7, p. 89. BESM (Bystrodeistvuiushchaia elektronnaia schetnaia mashina) is the High-Speed Electronic Calculating Machine, built at the Institute of Precise Mechanics and Computer Technology in Moscow. The euphemism "space enterprise" stands here for the Soviet intercontinental ballistic missile program, out of which the space program eventually developed. The term "cybernetics" is used here in the broad sense this word acquired in the Soviet Union in the 1960s and 1970s, when all computer applications fell under the rubric of cybernetics.

106. Iosif V. Stalin, "Rech' na predvybornom sobranii izbiratelei Stalinskogo okruga goroda Moskvy 9 fevralia 1946 g." (1946), in Stalin, *Sochineniia*, volume 3 [XIV], p. 19.

107. On the Soviet atomic project, see David Holloway, *Stalin and the Bomb: The Soviet Union and Atomic Energy, 1939–1956* (Yale University Press, 1994); Vladimir P. Vizgin, ed., *Istoriia sovetskogo atomnogo proekta: dokumenty, vospominaniia, issledovaniia*, vyp. 1 (Moscow: Ianus-K, 1998).

108. On Soviet rocketry, which developed in close connection with the space program, see Asif A. Siddiqi, *Challenge to Apollo: The Soviet Union and the Space Race, 1945–1974* (NASA, 2000), which includes an excellent bibliographic essay.

109. On the Soviet anti-missile defense program, see O. V. Golubev et al., "Problems of Control and Effectiveness Evaluation in the Development of the Soviet Antimissile Defense System. 1. Experimental Proving Ground System (System A)," *Journal of Computer and Systems Sciences International* 32 (1994), no. 2: 81–88; Grigorii Kisun'ko, *Sekretnaia zona: Ispoved' general'nogo konstruktora* (Moscow: Sovremennik, 1996). For a general overview of the Soviet defense industry, see Nikolai S. Simonov, *Voenno-promyshlennyi kompleks SSSR v 1920–1950-e gody: tempy ekonomicheskogo rosta, struktura, organizatsiia proizvodstva i upravleniie* (Moscow: ROSSPEN, 1996).

110. I. V. Bystrova and G. E. Riabov, "Voenno-promyshlennyi kompleks SSSR," in *Sovetskoe obshchestvo: Vozniknovenie, razvitie, istoricheskii final,* vol. 2, *Apogei i krakh stalinizma*, ed. V. Lel'chuk (Moscow: RGGU, 1997), p. 162.

111. Ibid., p. 167.

112. See "Tsikl statei po matematicheskoi tekhnike," *Uspekhi matematicheskikh nauk* 1 (1946): 3–174.

113. Mikhail L. Bykhovskii, "Novye amerikanskie schetno-analiticheskie mashiny," *Uspekhi matematicheskikh nauk* 2 (1947): 231–334. The next year, a somewhat more substantive article on American computing appeared; see Bykhovskii, "'ENIAK'—Elektronnaia schetnaia mashina," *Uspekhi matematicheskikh nauk* 3 (1948): 146–158.

114. Mikhail L. Bykhovskii, "Osnovy elektronnykh matematicheskikh mashin diskretnogo scheta," *Uspekhi matematicheskikh nauk* 4 (1949): 69–124.

115. Aleksandr Feklisov, *Za okeanom i na ostrove: Zapiski razvedchika* (Moscow: DEM, 1994), p. 105.

116. Mikhail A. Lavrent'ev, "Puti razvitiia sovetskoi matematiki," in *Obshchee sobranie Akademii nauk SSSR, posviashchennoe tridtsatiletiiu Velikoi Oktiabr'skoi sotsialisticheskoi revoliutsii*, ed. S. Vavilov (Moscow and Leningrad: AN SSSR, 1948), p. 402. On Lavrent'ev, see A. P. Epifanova and V. P. Il'ina, *Mikhail Alekseevich Lavrent'ev: Materialy k biobibliografii* (Moscow: Nauka, 1971). Lavrent'ev was an active participant in the nuclear weapons program; in 1952 he was even viewed as a potential replacement for the leadership of the thermonuclear weapons project if the first test of the Soviet hydrogen bomb were to fail—see Andrei Sakharov, *Memoirs* (Knopf, 1990), pp. 160–161.

117. "Spravka o vypolnenii pravitel'stvennykh zadanii v ITMVT," [1949] (RGASPI, f. 17, op. 132, d. 36, l. 48).

118. Kruzhkov and Zhdanov to Malenkov, 8 March 1950 (RGASPI, f. 17, op. 118, d. 758, ll. 22–23).

119. On Lebedev and his first computers, see Gregory D. Crowe and Seymour E. Goodman, "S. A. Lebedev and the Birth of Soviet Computing," *Annals of the History of Computing* 16 (1994), no. 1: 4–24; Boris N. Malinovskii, *Istoriia vychislitel'noi tekhniki v litsakh* (Kiev: Kit, 1995), pp. 17–81.

120. Malinovskii, *Istoriia vychislitel'noi tekhniki*, pp. 42–43.

121. Ibid., pp. 175–188.

122. Ibid., p. 43.

123. Ibid., p. 67.

124. Ibid., p. 42.

125. See Sergei A. Lebedev and Mstislav V. Keldysh, "Bol'shie schetnye matematicheskie mashiny," 1952 (ARAN, f. 1939, op. 2, d. 2, ll. 55, 57).

126. Malinovskii, *Istoriia vychislitel'noi tekhniki*, p. 48. Lesechko headed Special Design Bureau 245; Bazilevskii was the Bureau's chief designer.

127. "Godovoi bukhgalterskii otchet ITMVT," 1950, l. 22, Archive of the Institute of Precise Mechanics and Computer Technology.

128. See "Otchet ITMVT za 1950 g.," 1950 (ARAN, f. 1559, op. 1, d. 14, l. 49).

129. I. S. Mukhin, "O podbore, rasstanovke i vospitanii kadrov v institute," 10 April 1952 (TsAODM, f. 7341, op. 1, d. 4, l. 164).

130. Protokol zasedaniia partiinogo biuro ITMVT, 5 September 1950 (TsAODM, f. 7341, op. 1, d. 2, l. 119). Before World War II, Khrushchev led the Ukranian Party organization and Lavrent'ev headed the Institute of Mathematics in Kiev; they then "met many times and established very good, friendly relationship"; see R. G. Ianovskii's comments in *N. S. Khrushchev (1894–1971): Materialy nauchnoi konferentsii* (Moscow: RGGU, 1994), p. 164. In the late 1950s, Khrushchev publicly remarked: "I have known academician Lavrent'ev for many years. He is a good scientist." (*Pravda*, 2 July 1959)

131. Malinovskii, *Istoriia vychislitel'noi tekhniki*, p. 58.

132. Ibid., pp. 187–188.

133. The Department of Computational Mathematics was organized in 1949; Sobolev chaired it from 1952 to 1959. The Computation Center of Moscow University was established in 1955. See Ivan S. Berezin, "The Chair of Computer Mathematics and the Computation Center of Moscow University," *Soviet Cybernetics: Recent News Items* 3 (1969), no. 3: 38–44; Malinovskii, *Istoriia vychislitel'noi tekhniki*, pp. 280–289.

134. See K. Rutiskhauzer et al., "Elektronnye tsifrovye schetnye mashiny s programmnym upravleniem," *Voprosy raketnoi tekhniki* 2–5 (1952). This publication was a translation of Heinz von Rutishauser, Ambros Speiser, and Eduard Stiefel, *Programmgesteuerte digitale Rechengerate (elektronische Rechenmaschinen)* (Birkhäuser, 1951).

135. See Andrei P. Ershov and Mikhail R. Shura-Bura, "The Early Development of Programming in the USSR," in *A History of Computing in the Twentieth Century*, ed. N. Metropolis et al. (Academic, 1980), esp. pp. 154–155, 179; Rimma I.

Podlovchenko, "O nauchnom vklade A. A. Liapunova v oblasti teorii programmirovaniia," *Problemy kibernetiki* 32 (1977): 45–57.

136. Malinovskii, *Istoriia vychislitel'noi tekhniki*, pp. 189–190.

137. James Harford, *Korolev: How One Man Masterminded the Soviet Drive to Beat America to the Moon* (Wiley, 1997), pp. 220–221.

138. Feklisov, *Za okeanom i na ostrove*, p. 89.

139. See Anatolii I. Kitov, "Rol' akademika A. I. Berga v razvitii vychislitel'noi tekhniki i avtomatizirovannykh sistem upravleniia," in *Put' v bol'shuiu nauku: akademik Aksel' Berg*, ed. V. Siforov (Moscow: Nauka, 1988), p. 131; Kitov, "Chelovek, kotoryi vynes kibernetiku iz sekretnoi biblioteki" (interview), *Komp'iuterra* 1996, no. 43, 18 November: 44–45.

140. Computation Center 1 was organized in August 1954 to carry out calculations for the design of nuclear weapons and intercontinental ballistic missiles. See "27 TsNII—stareishaia nauchnaia organizatsiia Ministerstva oborony," *Chelovek i komp'iuter* 1996, no. 21–22, p. 4.

141. Kisun'ko, *Sekretnaia zona*, p. 277.

142. Golubev et al., "Problems of Control and Effectiveness Evaluation," p. 83.

143. Malinovskii, *Istoriia vychislitel'noi tekhniki*, pp. 68–70.

144. Ibid., p. 189.

145. Dmitrii Iu. Panov, "O malogabaritnykh elektronnykh vychislitel'nykh ustroistvakh i ikh primenenii dlia tselei upravleniia," 13 July 1953 (RGANI, f. 5, op. 17, d. 412, l. 78).

146. "27 TsNII—stareishaia nauchnaia organizatsiia," p. 4.

147. Protokol zasedaniia biuro Otdeleniia fiziko-matematicheskikh nauk, 6 September 1955 (ARAN, f. 471, op. 1/1947–1956, op. 1, d. 144a, l. 159).

148. Protokol zasedaniia komissii po rassmotreniiu zaiavok na vypolnenie vychislitel'nykh rabot, 13 December 1955 (ARAN, f. 1918, op. 1, d. 3, l. 4).

149. Mstislav V. Keldysh, "Osoboe mnenie," 13 December 1955 (ARAN, f. 1918, op. 1, d. 3, l. 1).

150. Malinovskii, *Istoriia vychislitel'noi tekhniki*, p. 54.

151. Quoted in Harford, *Korolev*, p. 220.

152. Nataliia Dubova, "Reabilitatsiia kibernetiki," *Computerworld Rossiia* 1999, no. 41, http://www.osp.ru/cw/1999/41/39.htm.

153. See Martin Campbell-Kelly and William Aspray, *Computer: A History of the Information Machine* (Basic Books, 1996), chapter 5.

154. Protokol zasedaniia partiinogo biuro ITMVT, 5 September 1950 (TsAODM, f. 7341, op. 1, d. 2, l. 119).

155. Protokol partiinogo sobraniia ITMVT, 8 September 1950 (TsAODM, f. 7341, op. 1, d. 2, l. 54).

156. "Zadachi kommunistov v sviazi s nachalom uchebnogo goda v seti partiinogo prosveshcheniia," 1 December 1952 (TsAODM, f. 7341, op. 1, d. 4, l. 87).

157. Bykhovskii, "Kibernetika—amerikanskaia lzhenauka," p. 125; Materialist, "Whom Does Cybernetics Serve?" p. 34.

158. Gladkov, "Kibernetika—psevdonauka," p. 59; Materialist, "Whom Does Cybernetics Serve?" p. 34.

159. Agapov, "Mark III, kal'kuliator," p. 2.

160. Lebedev and Keldysh, "Bol'shie schetnye matematicheskie mashiny," l. 10.

161. A. A. Sokolov "O perspektivnom plane izdanii perevodnykh rabot po fizike," 11 May 1954 (ARAN, f. 471, op. 1(47–56), d. 87a, l. 149).

162. See Ershov and Shura-Bura, "The Early Development of Programming."

163. Dmitrii Iu. Panov, "Ot redaktora perevoda," in *Bystrodeistvuiushchie vychislitel'nye mashiny* (Moscow: Izdatel'stvo inostrannoi literatury, 1952).

164. Nikolai A. Zheleznov, "Predislovie," in *Teoriia peredachi elektricheskikh signalov pri nalichii pomekh*, ed. Zheleznov (Moscow: Izdatel'stvo inostrannoi literatury, 1953), p. 6.

165. Malinovskii, *Istoriia vychislitel'noi tekhniki*, p. 31.

166. Eduard A. Meerovich, in "Obsuzhdenie doklada professora A. A. Liapunova 'Ob ispol'zovanii matematicheskikh mashin v logicheskikh tseliakh," (1954), in *Ocherki istorii informatiki*, ed. Pospelov and Fet, p. 64.

167. The Russian translation of Wiener's *Cybernetics* appeared in 1958.

168. "Obsuzhdenie doklada," p. 72.

169. Ibid., p. 75.

170. Malinovskii, *Istoriia vychislitel'noi tekhniki*, pp. 212–231.

171. Ibid., pp. 197–207.

172. Nataliia Dubova, "EVM i ekonomika—dve veshchi nesovmestnye?" *Computerworld Rossiia* 1999, no. 48, http://www.osp.ru/cw/1999/48/06.htm.

173. On the display value of large-scale Soviet technologies, see Paul R. Josephson, "'Projects of the Century' in Soviet History: Large-Scale Technologies from Lenin to Gorbachev," *Technology and Culture* 36 (1995), no. 3: 519–559.

174. Maiorov to Zhdanov, 22 November 1951 (RGASPI, f. 17, op. 133, d. 230, l. 156).

175. See Zhdanov to Smelov, 4 February 1952 (RGASPI, f. 17, op. 133, d. 230, l. 155); Glagolev and Danilov to the Technical Secretariat of the Central Committee, 9 February 1952 (RGASPI, f. 17, op. 133, d. 230, l. 158).

176. Protokol partiinogo sobraniia ITMVT, 5 May 1955 (TsAODM, f. 7341, op. 1, d. 7, l. 78).

177. Lavrent'ev to Suslov, 29 August 1951 (RGASPI, f. 17, op. 133, d. 174, l. 129). The newspaper article in question was E. Obodan, "Vychislitel'nuiu tekhniku—na sluzhbu tekhnicheskomu progressu," *Izvestiia*, 28 August 1951.

178. Parshin to Omel'chenko, 22 September 1951 (RGASPI, f. 17, op. 133, d. 174, l. 138).

179. Zhdanov, Slepov, and Romanov to Suslov, 1951 (RGASPI, f. 17, op. 133, d. 174, l. 147).

180. Ostrovitianov to Rumiantsev, 24 August 1954 (RGANI, f. 5, op. 17, d. 458, l. 106).

181. Vlasov to Rumiantsev, 24 July 1954 (RGANI, f. 5, op. 17, d. 458, l. 95).

182. The Ministry's position is described in Ostrovitianov to Rumiantsev, 24 August 1954 (RGANI, f. 5, op. 17, d. 458, l. 106).

183. Dmitrii Iu. Panov, "K voprosu o zasekrechivanii fakta nalichiia v SSSR elektronnykh schetnykh mashin," 11 December 1954 (RGANI, f. 5, op. 17, d. 509, l. 34).

184. Alston S. Householder, "Digital Computers in Eastern Europe," *Computers and Automation* 4 (1955), no. 12: 8–9.

185. Andrei N. Kolmogorov, "Kibernetika," in *Bol'shaia Sovetskaia entsiklopediia*, second edition, volume 51 (1958), p. 149.

Notes to Chapter 4

1. Adapted from Pavel Antokol'skii, *Sobranie sochinenii*, volume IV (Moscow: Khudozhestvennaia literatura, 1973), p. 335.

2. Boris Kagarlitsky, *The Thinking Reed: Intellectuals and the Soviet State from 1917 to the Present* (Verso, 1988), p. 161.

3. See Robert Conquest, *Power and Policy in the USSR* (St. Martin's, 1961); Carl A. Linden, *Khrushchev and the Soviet Leadership: with an epilogue on Gorbachev*, updated edition (Johns Hopkins University Press, 1990); Roy A. Medvedev, *Khrushchev* (Anchor Books, 1984); Roy A. Medvedev and Zhores A. Medvedev, *Khrushchev: The Years in Power* (Norton, 1978); William Taubman, Sergei Khrushchev, and Abbott Gleason, eds., *Nikita Khrushchev* (Yale University Press, 2000); William J. Tompson, *Khrushchev: A Political Life* (St. Martin's, 1995).

4. Rumiantsev to the Central Committee, April 1955 (RGANI, f. 5, op. 16, d. 536, l. 43).

5. Vladimir Pomerantsev, "Ob iskrennosti v literature," *Novyi mir* 1953, no. 12, pp. 218–245.

6. Kagarlitsky, *The Thinking Reed*, p. 140.

7. Petr Vail' and Aleksandr Genis, *60-e: Mir sovetskogo cheloveka* (Moscow: Novoe literaturnoe obozrenie, 1996), p. 100.

8. Viacheslav V. Ivanov, "Goluboi zver' (Vospominaniia)," *Zvezda* 1995, no. 3, pp. 166–167.

9. Vladimir Kudriavtsev, as quoted in Viktor Pekelis, *Cybernetic Medley* (Moscow: Mir, 1986), p. 186.

10. On Soviet science in the Khrushchev period, see Mark B. Adams, *Networks in Action: The Khrushchev Era, the Cold War and the Transformation of Soviet Science*, Trondheim Studies on East European Cultures and Societies, no. 3 (2000); David Holloway, "Scientific Truth and Political Authority in the Soviet Union," in *Political Opposition in One-Party States*, ed. L. Shapiro (Wiley, 1972); Zhores A.

Medvedev, *Soviet Science* (Norton, 1978), chapter 6; Alexander Vucinich, *Empire of Knowledge: The Academy of Sciences of the USSR (1917–1970)* (University of California Press, 1984), chapter 5.

11. See Medvedev, *Soviet Science*, pp. 60–67.

12. Postanovlenie Soveta Ministrov SSSR 1616-899s, "Ob uporiadochenii komandirovok sovetskikh spetsialistov za granitsu dlia izucheniia dostizhenii zarubezhnoi nauki i tekhniki i ob uluchshenii ispol'zovaniia ministerstvami i vedomstvami SSSR materialov etikh komandirovok," 2 September 1955.

13. Postanovlenie Prezidiuma Akademii nauk SSSR 56-04, "O merakh po uporiadocheniiu mezhdunarodnykh nauchnykh sviazei i uluchsheniiu ispol'zovaniia rezul'tatov nauchnykh komandirovok," 2 March 1956 (RGANI, f. 5, op. 35, d. 22, ll. 40–47).

14. Ibid., ll. 48–62.

15. Lebedev and Bazilevskii reportedly arrived late because they could not obtain American visas to pass through West Berlin.

16. Alston S. Householder, "Digital Computers in Eastern Europe," *Computers and Automation* 4 (1955), no. 12, p. 8.

17. Isaak S. Bruk, "O sostoianii i neotlozhnykh zadachakh razvitiia matematicheskogo mashinostroeniia v SSSR," ca. 12 January 1955 (RGANI, f. 5, op. 17, d. 507, l. 26).

18. Dmitrii Iu. Panov, "Bystrodeistvuiushchie vychislitel'nye mashiny: sostoianie i tendentsii razvitiia," February 1955 (RGANI, f. 5, op. 17, d. 512, ll. 8, 18–19).

19. Nesmeianov, Topchiev, and Lavren'tev to the Central Committee, May 1955 (RGANI, f. 5, op. 17, d. 512, ll. 35–38).

20. Iakovlev and Glagolev to the Central Committee, 21 April 1955 (RGANI, f. 5, op. 17, d. 512, ll. 29, 32).

21. Iakovlev and Serbin to the Central Committee, 8 August 1955 (RGANI, f. 5, op. 17, d. 512, l. 40).

22. Aleksandr Nesmeianov, "Nauka i proizvodtsvo," *Kommunist* 1956, no. 2, p. 45.

23. *Konferentsiia "Puti razvitiia sovetskogo matematicheskogo mashinostroeniia i priborostroeniia": Plenarnye zasedaniia* (Moscow, 1956), pp. 5, 78.

24. Nesmeianov, "Nauka i proizvodtsvo," p. 45.

25. "Reshenie koordinatsionnogo soveshchaniia po vychislitel'noi tekhnike," 6 June 1956 (RGANI, f. 5, op. 35, d. 31, l. 47).

26. See, e.g., A. Morozov, "'Dumaiushchie' mashiny," *Rabotnitsa* 1956, no. 10: 15–16; Iu. Petrovskii, "Na grani fantastiki," *Znanie—sila* 1956, no. 7: 17–24.

27. Petrovskii, "Na grani fantastiki," pp. 23–24.

28. Vucinich, *Empire of Knowledge*, p. 274.

29. See Andrei P. Ershov and Mikhail R. Shura-Bura, "The Early Development of Programming in the USSR," in *A History of Computing in the Twentieth Century*, ed. N. Metropolis et al. (Academic, 1980).

30. Aleksei A. Liapunov, "O nekotorykh obshchikh voprosakh kibernetiki" (1958), in Liapunov, *Problemy teoreticheskoi i prikladnoi kibernetiki*, ed. Sergei L. Sobolev (Moscow: Nauka, 1980), p. 56.

31. Quoted in *Problemy kibernetiki*, ed. V. Parin et al. (Moscow: Znanie, 1969), p. 124.

32. Aleksei A. Liapunov, "O roli matematiki v sovremennoi chelovecheskoi kul'ture" (1968), in Liapunov, *Problemy teoreticheskoi i prikladnoi kibernetiki*, p. 297.

33. Igor' A. Poletaev, *Signal: O nekotorykh poniatiiakh kibernetiki* (Moscow: Sovetskoe radio, 1958), p. 383.

34. Igor' A. Poletaev, "Chelovek v mire budushchego," in *Tochnye metody v issledovaniiakh kul'tury i iskusstva: Materialy k simpoziumu*, part I (Moscow, 1971), p. 109.

35. Nikolai Makarovich Nagornyi, interview with S. Gerovitch, Moscow, 22 July 1996.

36. Petr L. Kapitsa, "Teoriia. Eksperiment. Praktika" (1962), in Kapitsa, *Nauchnye trudy. Nauka i sovremennoe obshchestvo* (Moscow: Nauka, 1998), p. 285.

37. Grabar', Obruchev, and Sobolev to Khrushchev, April 1953 (RGANI, f. 5, op. 17, d. 402, l. 55ob).

38. Ibid., l. 55.

39. See I. R. Grinina and Simon S. Ilizarov, "Otdel nauki TsK KPSS v period politicheskogo krizisa 50-kh godov," in *Institut istorii estestvoznaniia i tekhniki im. S. I. Vavilova. Godichnaia nauchnaia konferentsiia, 1996*, ed. V. Orel (Moscow: Ianus-K, 1997).

40. "Nauka i zhizn'," *Kommunist* 1954, no. 5: 3–13.

41. Rumiantsev to the Central Committee, 7 March 1955 (RGANI, f. 5, op. 17, d. 463, l. 139).

42. Stenogramma zasedaniia Uchenogo soveta Instituta filosofii, 15 March 1955 (ARAN, f. 1922, op. 1, d. 758, ll. 47–48).

43. Postanovlenie Prezidiuma Akademii nauk SSSR "O nauchnoi deiatel'nosti Instituta filosofii," 3 June 1955 (RGANI, f. 5, op. 17, d. 524, l. 128).

44. Kammari to Nemchinov, 6 June 1955 (ARAN, f. 499, op. 2, d. 28, l. 19).

45. See Aleksandr D. Aleksandrov, "Dialektika i nauka," *Vestnik Akademii nauk SSSR* 1957, no. 6: 3–17; Aleksandrov, "Filosofskoe soderzhanie i znachenie teorii otnositel'nosti," *Voprosy filosofii* 1959, no. 1: 67–84.

46. R. David Gillespie, "The Politics of Cybernetics in the Soviet Union," in *Scientists and Public Affairs*, ed. A. Teich (MIT Press, 1974), p. 262.

47. Stenogramma doklada professora Kol'mana "Nekotorye problemy kibernetiki," 4 April 1956 (ARAN, f. 1922, op. 1, d. 805, l. 64).

48. Ernest Kolman, "Is It Possible to Prove or Disprove Mendelism by Mathematical and Statistical Methods?" *Comptes Rendus (Doklady) de l'Académie des Sciences de l'URSS* 28 (1940), no. 9, p. 837.

49. Ernest Kolman, "What Is Cybernetics?" (1955), *Behavioral Science* 4 (1959), no. 2, p. 144.

50. On Kolman, see Simon S. Ilizarov, "Ernest Kol'man, Nikita Khrushchev i IIET," *Voprosy istorii estestvoznaniia i tekhniki* 1998, no. 1: 152–156; Anatolii S. Sonin, *"Fizicheskii idealizm": Istoriia odnoi ideologicheskoi kampanii* (Moscow: Fizmatlit, 1994), pp. 32–42. See also Kolman's memoirs: Arnost Kolman, "The Adventure of Cybernetics in the Soviet Union," *Minerva* 16 (1978), no. 3: 416–424; Arnosht Kol'man, *My ne dolzhny byli tak zhit'* (Chalidze, 1982).

51. Joravsky, *The Lysenko Affair*, p. 361.

52. Ernest Kol'man, "Vreditel'stvo v nauke," *Bol'shevik* 1931, no. 2: 75–76, as quoted in Graham, *Science in Russia and the Soviet Union*, p. 148.

53. Ernest Kol'man, "Protiv noveishikh otkrovenii burzhuaznogo mrakobesiia," *Bol'shevik* 1933, no. 12, p. 91.

54. Ernest Kol'man, "Politika, ekonomika i . . . matematika," in *Na bor'bu za materialisticheskuiu dialektiku v matematike* (Moscow and Leningrad, 1931).

55. See Graham, *Science in Russia*, pp. 148–151.

56. Kolman to Khrushchev, 8 April 1953 (RGANI, f. 5, op. 17, d. 412, l. 21).

57. Ibid., l. 22.

58. Kolman remained a member of the Czechoslovakian Academy of Sciences and often visited Prague. The suppression of the "Prague spring" in 1968 left him totally disillusioned. In 1976, he emigrated from the Soviet Union and joined his daughter in Sweden.

59. Kolman, "What Is Cybernetics?" p. 146.

60. Ibid., p. 141.

61. Ibid., p. 145.

62. Kol'man, *My ne dolzhny byli tak zhit'*, p. 305.

63. David Holloway, "Innovation in Science—the Case of Cybernetics in the Soviet Union," *Science Studies* 4 (1974), p. 308.

64. Materialist (pseudonym), "Whom Does Cybernetics Serve?" (1953), *Soviet Cybernetics Review* 4 (1974), no. 2, p. 44.

65. Kolman, "What Is Cybernetics?" p. 146.

66. Ernest Kol'man, "O filosofskikh i sotsial'nykh problemakh kibernetiki," in *Filosofskie voprosy kibernetiki*, ed. V. Il'in et al. (Moscow: Izdatel'stvo sotsial'no-ekonomicheskoi literatury, 1961), p. 91.

67. Ibid., p. 92. See also Kolman, "What Is Cybernetics?" p. 143.

68. Kol'man, *My ne dolzhny byli tak zhit'*, p. 306.

69. In April 1959, Kolmogorov and two other mathematicians, Vladimir A. Uspenskii and Delir G. Lakhuti, presented Liapunov with a copy of the Russian edition of William Ross Ashby's *Introduction to Cybernetics* and signed it "to the father of Soviet cybernetics." See *Ocherki istorii informatiki*, ed. Pospelov and Fet, photo insert between pp. 256 and 257.

70. On Liapunov, see R. I. Kuz'menko and Natal'ia A. Liapunova, comps. *Aleksei Andreevich Liapunov: Materialy k biobibliografii* (Moscow: Nauka, 1996); Pospelov and Fet, eds., *Ocherki istorii informatiki*, pp. 184–213, 463–483.

71. See Mikhail G. Gaaze-Rapoport, "O stanovlenii kibernetiki v SSSR," in *Ocherki istorii informatiki*, ed. Pospelov and Fet, pp. 239–249.

72. Isaak S. Bruk, "Ob upravliaiushchikh mashinakh," *Priroda* 1955, no. 5: 17–26.

73. Aleksei A. Liapunov, "Otzyv o stat'e chlena-korrespondenta AN SSSR I. S. Bruka," n.d. (ARAN, f. 1875).

74. On Sobolev, see N. S. Bakhvalov et al., "Sergei L'vovich Sobolev (on his eightieth birthday)," *Russian Mathematical Surveys* 43 (1988), no. 5: 1–14; Andrei V. Bitsadze, ed., *Sergei L'vovich Sobolev (K 60-letiiu so dnia rozhdeniia)* (Novosibirsk: Nauka, 1969).

75. Quoted in Bakhvalov et al., "Sergei L'vovich Sobolev," p. 7.

76. On Kitov, see Boris N. Malinovskii, *Akademik V. Glushkov: Stranitsy zhizni i tvorchestva* (Kiev: Naukova dumka, 1993), pp. 83–84; Anatolii I. Kitov, "Chelovek, kotoryi vynes kibernetiku iz sekretnoi biblioteki" (interview), *Komp'iuterra* 1996, no. 43, 18 November: 44–45.

77. See Anatolii I. Kitov, "Rol' akademika A. I. Berga v razvitii vychislitel'noi tekhniki i avtomatizirovannykh sistem upravleniia," in *Put' v bol'shuiu nauku: akademik Aksel' Berg*, ed. V. Siforov (Moscow: Nauka, 1988), p. 131.

78. See Anatolii I. Kitov, *Elektronnye tsifrovye mashiny* (Moscow: Sovetskoe radio, 1956).

79. Sergei L. Sobolev, Anatolii I. Kitov, and Aleksei A. Liapunov, "Osnovnye cherty kibernetiki," *Voprosy filosofii* 1955, no. 4, p. 136.

80. Poletaev, *Signal*, p. 23.

81. Sobolev, Kitov, and Liapunov, "Osnovnye cherty kibernetiki," p. 136.

82. Ibid., p. 136.

83. Ibid., p. 140.

84. Ibid., p. 146.

85. Ibid., p. 147.

86. Holloway, "Innovation in Science," p. 316.

87. Sobolev, Kitov, and Liapunov, "Osnovnye cherty kibernetiki," p. 146.

88. "Obsuzhdenie stat'i S. L. Soboleva, A. A. Liapunova i A. I. Kitova 'Osnovnye cherty kibernetiki' v redaktsii zhurnala 'Voprosy filosofii,'" in *Ocherki istorii informatiki*, ed. Pospelov and Fet, p. 110.

89. Sobolev, Kitov, and Liapunov, "Osnovnye cherty kibernetiki," pp. 146, 148.

90. "Obsuzhdenie stat'i," p. 108.

91. Ibid., pp. 108–109.

92. Ibid., 109.

93. Ibid.

94. Sobolev, Kitov, and Liapunov, “Osnovnye cherty kibernetiki,” p. 143.

95. Sergei L. Sobolev, “Vystuplenie na soveshchanii,” in *Filosofskie problemy sovremennogo estestvoznaniia*, ed. P. Fedoseev (Moscow: AN SSSR, 1959), p. 260.

96. Sergei L. Sobolev, “Zakliuchitel’noe slovo,” in *Filosofskie problemy*, ed. Fedoseev, p. 572.

97. Kirillin and Frolov to the Central Committee, 31 October 1958 (RGANI, f. 5, op. 35, d. 76, l. 162).

98. Sergei L. Sobolev and Aleksei A. Liapunov, “Kibernetika i estestvoznanie,” in *Filosofskie problemy*, ed. Fedoseev, p. 258.

99. Sobolev, “Zakliuchitel’noe slovo,” p. 573.

100. “O zadachakh razrabotki voprosov estestvoznaniia,” in *Filosofskie problemy*, ed. Fedoseev, p. 604.

101. Kirillin and Frolov to the Central Committee, 31 October 1958 (RGANI, f. 5, op. 35, d. 76, l. 162).

102. See Julii J. Kerkis and Aleksei A. Liapounoff, “Segregation in Hybrids,” *Comptes Rendus (Doklady) de l’Académie des Sciences de l’URSS* 31 (1941), no. 1: 47–50.

103. On the culture of “learned circles,” or private study groups, in Russia, see Daniel A. Aleksandrov, “The Historical Anthropology of Science in Russia,” *Russian Studies in History* 34 (1995), no. 2: 62–91.

104. Natal’ia A. Liapunova and Nikolai N. Vorontsov, “Delo sester Liapunovykh,” *Znanie—sila* 1998, no. 8, p. 43.

105. For the original of this letter, see RGANI, f. 5, op. 17, d. 515, ll. 110–131ob.

106. “Iz pis’ma 297 sovetskikh uchenykh (‘pis’mo trekhsot’) v Prezidium TsK KPSS o sostoianii biologichekoi nauki v SSSR” (May-October 1955), in *Khrestomatiia po otechestvennoi istorii (1946–1995)*, ed. A. Kiselev and E. Shchagin (Moscow: VLADOS, 1996), pp. 458, 460. A complete text of this letter was reprinted in *Pravda* (27 January 1989).

107. See RGANI, f. 5, op. 17, d. 515, ll. 267–277.

108. See RGANI, f. 5, op. 17, d. 515, ll. 270, 277.

109. Kirillin to the Central Committee, 8 February 1956 (RGANI, f. 5, op. 17, d. 515, l. 108).

110. Protokol partiinogo sobraniia biologo-pochvennogo fakul’teta MGU, 22 December 1955 (TsAODM, f. 478, op. 5, d. 51, l. 132).

111. Ibid., l. 122.

112. Ibid., l. 115.

113. Ibid.

114. Protokol zasedaniia partiinogo biuro biologo-pochvennogo fakul’teta MGU, 14 February 1956 (TsAODM, f. 478, op. 5, d. 73, l. 29).

115. Liapunova and Vorontsov, “Delo sester Liapunovykh,” p. 46.

116. Stenogramma rasshirennogo zasedaniia partiinogo biuro biologo-pochvennogo fakul'teta MGU, 28 February 1956 (TsAODM, f. 478, op. 5, d. 73, l. 52). Studitskii was the author of "Fly-lovers, Man-haters," a vituperative attack on geneticists.

117. Ibid., l. 68.

118. Ibid., l. 106.

119. Stenogramma zasedaniia partiinogo komiteta MGU, 29 February 1956 (TsAODM, f. 478, op. 3, d. 44, ll. 172–173).

120. Ibid., ll. 177–178.

121. Ibid., ll. 201a, 205–206.

122. Ibid., ll. 214–215.

123. Ibid., l. 233.

124. See Protokol zasedaniia partiinogo biuro Otdeleniia prikladnoi matematiki, 27 September 1956 (TsAODM, f. 8033, op. 1, d. 3, l. 63).

125. Kapitsa, "Teoriia. Eksperiment. Praktika," p. 285.

126. Protokol zakrytogo partiinogo sobraniia Instituta matematiki, 10 January 1957 (TsAODM, f. 7334, op. 1, d. 9, l. 2).

127. Protokol partiinogo sobraniia Otdeleniia prikladnoi matematiki, 23 August 1956 (TsAODM, f. 8033, op. 1, d. 3, l. 32).

128. My translation does not express the sarcastic tone of the original fully.

129. Aleksei A. Liapunov, "O filosofii," n.d. ; Liapunov papers.

130. Holloway, "Innovation in Science," pp. 322–323.

131. See Graham, *Science, Philosophy, and Human Behavior in the Soviet Union*.

132. Protokol zakrytogo partiinogo sobraniia Instituta matematiki, 31 January 1957 (TsAODM, f. 7334, op. 1, d. 9, l. 32).

133. Ibid., l. 10.

134. Ibid., l. 9.

135. Protokol zakrytogo partiinogo sobraniia Instituta matematiki, 10 January 1957 (TsAODM, f. 7334, op. 1, d. 9, l. 5).

136. Protokol partiinogo sobraniia Otdeleniia prikladnoi matematiki, 23 August 1956 (TsAODM, f. 8033, op. 1, d. 3, l. 32).

137. N. I. Zolotukhin, "O nachale uchebnogo goda v seti partiinogo prosveshcheniia," 13 September 1956 (TsAODM, f. 8033, op. 1, d. 3, l. 37).

138. K. I. Babenko, "Otchet o rabote partiinogo biuro," 27 June 1957 (TsAODM, f. 8033, op. 1, d. 4, l. 49).

139. Protokol otchetno-vybornogo partiinogo sobraniia Otdeleniia prikladnoi matematiki, 24 June 1958 (TsAODM, f. 8033, op. 1, d. 5, l. 66).

140. "Dokladnaia zapiska o sostoianii radioelektroniki v SSSR i za rubezhom i neobkhodimykh meropriiatiiakh dlia ee razvitiia v SSSR," March 1955, RGAE, f. 300, op. 1, d. 797, l. 64; as quoted in Nikolai S. Simonov, *Voenno-promyshlennyi*

kompleks SSSR v 1920–1950-e gody: tempy ekonomicheskogo rosta, struktura, organizatsiia proizvodstva i upravleniie (Moscow: ROSSPEN, 1996), pp. 259–260.

141. "Vazhneishie zadachi razvitiia nauki v shestoi piatiletke," October 1955 (RGANI, f. 5, op. 35, d. 2, l. 31). The three Soviet machines mentioned in the report included one BESM computer, built at the Academy of Sciences Institute of Precise Mechanics and Computer Technology, and two STRELA computers, built under the Ministry of Machine and Instrument Construction.

142. Ibid., ll. 6, 20–21.

143. Viktor A. Il'in, "Na kongresse po kibernetike," *Vestnik Akademii nauk* 1956, no. 11, p. 75.

144. Viktor A. Il'in, "Kongress po kibernetike v Namiure (Bel'giia): Kratkii obzor," in *Filosofskie voprosy kibernetiki*, ed. Il'in et al. (Moscow: Izdatel'stvo sotsial'no-ekonomicheskoi literatury, 1961), p. 350.

145. Viktor A. Il'in, et al., "Otchet sovetskoi delegatsii na mezhdunarodnom kongresse po kibernetike v g. Namiure," 7 August 1956 (ARAN, f. 395, op. 17, d. 43, l. 13).

146. Aleksandr N. Nesmeianov, "Vstupitel'noe slovo," in *Sessiia Akademii nauk SSSR po nauchnym problemam avtomatizatsii proizvodstva, 15–20 oktiabria 1956 g.: Plenarnye zasedaniia*, ed. V. Trapeznikov (Moscow: AN SSSR, 1957), p. 5.

147. Aleksandr N. Nesmeianov, "Zakliuchitel'noe slovo," in *Sessiia Akademii nauk SSSR*, ed. Trapeznikov, p. 265.

148. Mstislav V. Keldysh, Aleksei A. Liapunov, and Mikhail R. Shura-Bura, "Matematicheskie voprosy teorii schetnykh mashin," in *Sessiia Akademii nauk*, ed. Trapeznikov, p. 128.

149. Aleksandr A. Dorodnitsyn, in *Sessiia Akademii nauk*, ed. Trapeznikov, p. 156.

150. Andrei N. Kolmogorov, "Kibernetika," in *Bol'shaia Sovetskaia entsiklopediia*, second edition, volume 51 (1958), p. 150.

Notes to Chapter 5

1. Aksel' I. Berg, "Kibernetiku—na sluzhbu kommunizmu (Vvedenie)," in *Kibernetiku—na sluzhbu kommunizmu*, volume 1, ed. A. Berg (Moscow and Leningrad: Gosenergoizdat, 1961), p. 11.

2. Trofim D. Lysenko, "In Response to an Article by A. N. Kolmogoroff," *Comptes Rendus (Doklady) de l'Académie des Sciences de l'URSS* 28 (1940), no. 9, p. 833.

3. Andrei A. Markov, "Ob otnoshenii fizicheskikh zakonov k biologicheskim," in *O sushchnosti zhizni*, ed. G. Frank and A. Kuzin (Moscow: Nauka, 1964), p. 169.

4. Vasilii V. Parin, "Primenenie kibernetiki v biologii i meditsine," in *Biologicheskie aspekty kibernetiki*, ed. A. Kuzin (Moscow: AN SSSR, 1962), p. 22.

5. Irina Radunskaia, *Aksel' Berg—chelovek XX veka* (Moscow: Molodaia gvardiia, 1971), p. 365.

6. Parin, "Primenenie kibernetiki v biologii i meditsine," p. 22.

7. Vasilii V. Parin et al., eds., *Problemy kibernetiki: Nekotorye itogi i problemy filosofsko-metodologicheskikh issledovanii* (Moscow: Znanie, 1969), p. 40.

8. Leonid P. Kraizmer, *Kibernetika* (Leningrad: Ekonomika, 1977), p. 17.

9. Mstislav V. Keldysh, Aleksei A. Liapunov, and Mikhail R. Shura-Bura, "Matematicheskie voprosy teorii schetnykh mashin," in *Sessiia Akademii nauk SSSR po nauchnym problemam avtomatizatsii proizvodstva, 15–20 oktiabria 1956 g.: Plenarnye zasedaniia*, ed. V. Trapeznikov (Moscow: AN SSSR, 1957), p. 129.

10. See Aleksei A. Liapunov and Sergei V. Iablonskii, "Teoreticheskie problemy kibernetiki" (1963), in Liapunov, *Problemy teoreticheskoi i prikladnoi kibernetiki*, ed. S. Sobolev (Moscow: Nauka, 1980).

11. "Nauka li kibernetika?" *Znanie—sila* 1957, no. 3, p. 48.

12. On Berg, see I. V. Brenev and A. P. Epifanova, compilers, *Aksel' Ivanovich Berg: Materialy k biobibliografii* (Moscow: Nauka, 1965); Radunskaia, *Aksel' Berg*; I. A. Riabinin et al., *Akademik Aksel' Ivanovich Berg (K stoletiiu so dnia rozhdeniia)* (Moscow: Gosudarstvennyi Politekhnicheskii muzei, 1993); Vladimir I. Siforov, ed., *Put' v bol'shuiu nauku: akademik Aksel' Berg* (Moscow: Nauka, 1988).

13. Aleksandr G. Spirkin, "Rovesnik Sovetskoi vlasti (Vospominaniia)," *Vestnik* 9.2 (1997), no. 14, p. 57.

14. Berg to Liapunov, 9 April 1959; Liapunov papers.

15. Stenogramma zasedaniia prezidiuma Akademii nauk SSSR, 10 April 1959 (ARAN, f. 2, op. 3a, d. 236, l. 16). For the published version of Berg's report, see Aksel' I. Berg, "Osnovnye voprosy kibernetiki" (1959), in Berg, *Izbrannye trudy*, volume II (Moscow: Energiia, 1964).

16. Stenogramma, l. 20.

17. Ibid.

18. Protokol No. 1 zasedaniia Nauchnogo Soveta po kibernetike pri Prezidiume Akademii nauk SSSR, 26 June 1959 (ARAN, f. 1807, op. 1, d. 1, l. 1).

19. Vadim A. Ratner, "Aleksei Andreevich Liapunov," in *Ocherki istorii informatiki*, ed. Pospelov and Fet, p. 382.

20. Mark B. Adams, "Biology after Stalin," *Survey* 23 (1977–78), no. 1, p. 55.

21. Sergei L. Sobolev and Aleksei A. Liapunov, "Kibernetika i estestvoznanie," in *Filosofskie problemy sovremennogo estestvoznaniia: Trudy Vsesoiuznogo soveshchaniia po filosofskim voprosam estestvoznaniia*, ed. P. Fedoseev (Moscow: AN SSSR, 1959), pp. 251–252 (emphasis added).

22. Sergei L. Sobolev, "Vystuplenie na soveshchanii," in *Filosofskie problemy*, ed. Fedoseev, p. 266 (emphasis added).

23. Sobolev and Liapunov, "Kibernetika i estestvoznanie," p. 252.

24. Natal'ia A. Liapunova and Nikolai N. Vorontsov, "Delo sester Liapunovykh," *Znanie—sila* 1998, no. 8, p. 44.

25. See Raissa L. Berg, *Acquired Traits: Memoirs of a Geneticist from the Soviet Union* (Viking, 1988), p. 305. Raisa Berg is the daughter of academician Lev Berg; she is not related to Aksel' Berg.

26. Raisa L. Berg and Nikolai V. Timofeev-Resovskii, "O putiakh evoliutsii genotipa," *Problemy kibernetiki* 5 (1961), p. 183.

27. Berg, *Acquired Traits*, p. 220.

28. Quoted in Radunskaia, *Aksel' Berg*, pp. 292–298.

29. Rybkin to Berg, 10 January 1962; Liapunov papers.

30. Raisa L. Berg, "Otvet na Zamechaniia o stat'iakh po obshchei biologii v sbornike 'Problemy kibernetiki,'" 1962; Liapunov papers.

31. "O trudnostiakh izzhitiia posledstvii kul'ta lichnosti v biologicheskoi nauke," n.d. ; Liapunov papers.

32. Aksel' I. Berg, "Kibernetika i nauchno-tekhnicheskii progress," in *Biologicheskie aspekty kibernetiki*, ed. Kuzin, p. 20.

33. Parin, "Primenenie kibernetiki v biologii i meditsine," p. 32.

34. See *Pravda* (16 April 1962).

35. Andrei Kolmogorov, "Avtomaty i zhizn'," in *Vozmozhnoe i nevozmozhnoe v kibernetike*, ed. A. Berg and E. Kol'man (Moscow: AN SSSR, 1963), p. 11.

36. K. Iu. Kostriukova, in *Filosofskie problemy*, ed. Fedoseev, p. 481.

37. Sobolev, "Zakliuchitel'noe slovo," in *Filosofskie problemy*, ed. Fedoseev, p. 572.

38. Aleksei A. Liapunov, "Ob upravliaiushchikh sistemakh zhivoi prirody i obshchem ponimanii zhiznennykh protsessov" (1963), in Liapunov, *Problemy teoreticheskoi i prikladnoi kibernetiki*, ed. S. Sobolev (Moscow: Nauka, 1980).

39. Aleksei A. Liapunov and Andrei G. Malenkov, "Logicheskii analiz stroeniia nasledstvennoi informatsii" (1962), in Liapunov, *Problemy teoreticheskoi i prikladnoi kibernetiki*.

40. Kobozev to Liapunov, 24 May 1962; Liapunov papers.

41. Vadim A. Ratner, "'Mamont' (zametki o N. V. Timofeeve-Resovskom)," in *Nikolai Vladimirovich Timofeev-Resovskii: Ocherki. Vospominaniia. Materialy*, ed. N. Vorontsov (Moscow: Nauka, 1993), p. 298.

42. Nikolai and Elena Timoféeff-Ressovsky to Liapunov, 5 January 1956, in Nikolai V. Timofeev-Resovskii, *Vospominaniia: Istorii, rasskazannye im samim, s pis'mami, fotografiiami i dokumentami*, ed. N. Dubrovina (Moscow: Soglasie, 2000), p. 489.

43. Nikolai V. Timofeev-Resovskii, "Istorii," in ibid., p. 236.

44. Nikolai and Elena Timoféeff-Ressovsky to Liapunov, 5 October 1957, in ibid., p. 509. The article Timoféeff-Ressovsky mentions here would later be published as Nikolai V. Timofeev-Resovskii, "Mikroevoliutsiia: Elementarnye iavleniia, material i faktory mikroevoliutsionnogo protsessa," *Botanicheskii zhurnal* 43 (1958), no. 3: 317–336.

45. Nikolai and Elena Timoféeff-Ressovsky to Liapunov, 28 October 1957, in Timofeev-Resovskii, *Vospominaniia*, p. 512.

46. Timofeev-Resovskii, "Istorii," p. 256.

47. Timoféeff-Ressovsky to Liapunov, 9 February 1959, in Timofeev-Resovskii, *Vospominaniia*, p. 516.

48. Nikolai V. Timofeev-Resovskii, "Nekotorye problemy radiatsionnoi biotsenologii," *Problemy kibernetiki* 12 (1964): 201–232.

49. Liapunov, "Ob upravliaiushchikh sistemakh."

50. Aleksei A. Liapunov, "O kiberneticheskikh voprosakh biologii" (1972), in Liapunov, *Problemy teoreticheskoi i prikladnoi kibernetiki*, p. 235.

51. Raisa L. Berg and Aleksei A. Liapunov, "Predislovie," in Ivan I. Shmal'gauzen, *Kiberneticheskie voprosy biologii* (Novosibirsk: Nauka, 1968), p. 13.

52. Ibid.

53. Vadim A. Ratner, *Geneticheskie upravliaiushchie sistemy* (Novosibirsk: Nauka, 1966), pp. 7, 170.

54. On Ratner's research program, see Ratner, "Aleksei Andreevich Liapunov"; Vadim A. Ratner, *Kontseptsiia molekuliarno-geneticheskikh sistem upravleniia* (Novosibirsk: Nauka, 1993).

55. Parin, "Primenenie kibernetiki v biologii i meditsine," pp. 22, 32.

56. Nikolai A. Bernshtein, "Methods for Developing Physiology as Related to the Problems of Cybernetics" (1962), in *A Handbook of Contemporary Soviet Psychology*, ed. M. Cole and I. Maltzman (Basic Books, 1969), p. 448.

57. Nicholas Bernstein, "Some Emergent Problems of the Regulation of Motor Acts" (1957), in *The Co-ordination and Regulation of Movements*, p. 131.

58. For example, Bernshtein argued (ibid., pp. 129–130) that, in the case of a hand reaching for an object, the feedback-controlled coordination of movements was aimed at minimizing the current deviation from a planned path, rather than the current distance between the hand and the object, as Wiener and Rosenbleuth had suggested.

59. See Bernshtein, "Methods for Developing Physiology."

60. See Mikhail L. Tsetlin et al., "Mathematical Simulation of the Principles of the Functioning of the Central Nervous System" (1962), in Tsetlin, *Automaton Theory and Modeling of Biological Systems* (Academic, 1973), p. 137.

61. Nicholas Bernstein, "Trends in Physiology and Their Relation to Cybernetics" (1962), in Bernstein, *The Co-ordination and Regulation of Movements*, p. 178.

62. Nikolai A. Bernshtein, "Puti razvitiia fiziologii i sviazannye s nimi zadachi kibernetiki," in *Biologicheskie aspekty kibernetiki*, ed. Kuzin, p. 62.

63. Nikolai A. Bernshtein, "Novye linii razvitiia v fiziologii i ikh sootnoshenie s kibernetikoi" (1963), in Bernshtein, *Biomekhanika i fiziologiia dvizhenii*, ed. V. Zinchenko (Moscow and Voronezh, 1997), p. 457.

64. For the proceedings of this conference, see *Filosofskie voprosy fiziologii vysshei nervnoi deiatel'nosti i psikhologii*, ed. P. Fedoseev et al. (Moscow: AN SSSR, 1963).

65. Bernshtein, "Methods for Developing Physiology," p. 443.

66. I. B. Lekhtman of the Lesgaft Institute of Physical Culture, Leningrad, in *Filosofskie voprosy fiziologii*, ed. Fedoseev et al., p. 558.

67. A. A. Zubkov of the Medical Institute, Kishinev, in *Filosofskie voprosy fiziologii*, ed. Fedoseev et al., p. 584. Aristotle called the form or "vital function" (the "soul," or inner activity) of an organism, as opposed to the passive matter of which it was composed, *entelechy*. This notion was revived at the turn of the twentieth century by the German biologist and philosopher Hans Driesch in his vitalistic theory. Western cybernetics-minded biologists also had reservations about the notion of teleology and preferred to replace it with the less offensive *teleonomy*, which described adaptation as the activation of a preexisting finite storage of genetic information. See Kay, *Who Wrote the Book of Life?*, p. 196.

68. Ivan I. Artobolevskii and Aron E. Kobrinskii, "Zhivoe sushchestvo i tekhnicheskoe ustroistvo" (1963), in *Kibernetika—neogranichennye vozmozhnosti i vozmozhnye ogranicheniia*, ed. V. Pekelis (Moscow: Nauka, 1979), pp. 64–65.

69. Mikhail M. Bongard of the Institute of Biophysics, Moscow, in *Filosofskie voprosy fiziologii*, ed. Fedoseev, p. 672.

70. Ibid.

71. See Mikhail Bongard, *Pattern Recognition* (Spartan Books, 1970).

72. See Liapunov and Iablonskii, "Teoreticheskie problemy kibernetiki."

73. See Aleksei A. Liapunov, "O nekotorykh obshchikh voprosakh kibernetiki" (1958), in Liapunov, *Problemy teoreticheskoi i prikladnoi kibernetiki*, pp. 68–69.

74. I. I. Gal'perin, "O reflektornoi prirode upravliaiushchikh mashin (Otvet inzhenera fiziologam)," *Voprosy filosofii* 1957, no. 4, p. 162.

75. Ibid., p. 159.

76. Ibid., p. 167.

77. Ibid., p. 168.

78. See Nikolai A. Bernshtein, "Modeli kak sredstvo izucheniia nervno-dvigatel'nykh protsessov" (1958), in Bernshtein, *Biomekhanika i fiziologiia dvizhenii*, p. 399.

79. Sergei Sobolev, "Da, eto vpolne ser'ezno!" in *Vozmozhnoe i nevozmozhnoe*, ed. Berg and Kol'man, p. 83.

80. Iurii P. Frolov, "Dialektika zhivoi prirody i sovremennaia kibernetika," in *Filosofskie voprosy kibernetiki*, ed. V. Il'in et al. (Moscow: Izdatel'stvo sotsial'no-ekonomicheskoi literatury, 1961), p. 316.

81. Petr K. Anokhin, "Fiziologiia i kibernetika" (1957), in Anokhin, *Filosofskie aspekty teorii funktsional'noi sistemy: Izbrannye trudy*, ed. F. Konstantinov et al. (Moscow: Nauka, 1978), p. 210.

82. B. K. Gurevich, "'Razumnye' avtomaty i vysshie funktsii mozga," *Voprosy psikhologii* 1959, no. 4, p. 11.

83. Nikolai A. Bernshtein, "Predislovie: O perspektivakh matematiki v biokibernetike," in Vladimir I. Chernysh and Anatolii V. Napalkov, *Matematicheskii apparat biologicheskoi kibernetiki* (Moscow: Meditsina, 1964), p. 4.

84. Bernstein, "Trends in Physiology," p. 173.

85. On Tsetlin, see Viacheslav V. Ivanov, "Iz istorii kibernetiki v SSSR. Ocherk zhizni i deiatel'nosti M. L. Tsetlina," in *Ocherki istorii informatiki*, ed. Pospelov and Fet.

86. Mikhail L. Tsetlin et al., "Mathematical Simulation," p. 132.

87. Ibid., pp. 150, 152.

88. See Viacheslav E. Demidov, "U istokov fiziologii aktivnosti. Nikolai Aleksandrovich Bernshtein i razvitie otechestvennykh biokiberneticheskikh issledovanii," in *Kibernetika: proshloe dlia budushchego. Etiudy po istorii otechestvennoi kibernetiki*, ed. B. Biriukov (Moscow: Nauka, 1989), esp. pp. 149–150; Levan V. Chkhaidze, *Koordinatsiia proizvol'nykh dvizhenii cheloveka v usloviiakh kosmicheskogo poleta* (Moscow: Nauka, 1965), with Bernshtein's preface.

89. See Nicholas Bernstein, *The Co-ordination and Regulation of Movements* (Pergamon, 1967).

90. J. Requin, A. Semjen, and M. Bonnet, "Bernstein's Purposeful Brain," in *Human Motor Actions*, ed. H. Whiting (North-Holland, 1984), p. 467.

91. Ibid., p. 471.

92. Viacheslav Vs. Ivanov, "Goluboi zver' (Vospominaniia)," *Zvezda* 1995, no. 3, pp. 166–167.

93. Isaak I. Revzin, *Sovremennaia strukturnaia lingvistika: Problemy i metody*, ed. V. Ivanov (Moscow: Nauka, 1977), p. 45.

94. Iurii Lotman, "Literaturovedenie dolzhno stat' naukoi," *Voprosy literatury* 1967, no. 1, p. 95.

95. Roman Jakobson, "On Realism in Art" (1921), in Jakobson, *Language in Literature*, ed. Pomorska and Rudy (Belknap, 1987), p. 19.

96. Czech weekly *ČIN* (31 October 1929), as quoted in Roman Jakobson, "Retrospect," in Jakobson, *Selected Writings*, volume II: *Word and Language* (Mouton, 1971), p. 711.

97. Viacheslav Vs. Ivanov, "Iz proshlogo semiotiki, strukturnoi lingvistiki i poetiki," in *Ocherki istorii informatiki*, ed. Pospelov and Fet, pp. 314–315.

98. Vladimir A. Uspenskii, "Serebrianyi vek strukturnoi, prikladnoi i matematicheskoi lingvistiki v SSSR i V. Iu. Rozentsveig: Kak eto nachinalos' (zametki ochevidtsa)," in *Ocherki istorii informatiki*, ed. Pospelov and Fet, p. 277.

99. Ibid., p. 276.

100. Vladimir A. Uspenskii, "Predvarenie dlia chitatelei 'Novogo literaturnogo obozreniia' k semioticheskim poslaniiam A. N. Kolmogorova," *Novoe literaturnoe obozrenie* 24 (1997), p. 130.

101. See Dmitrii M. Segal, "Mezhvuzovskaia nauchnaia konferentsiia po prikladnoi lingvistike," *Mashinnyi perevod i prikladnaia lingvistika* 5 (1961), p. 96.

102. See Isaak I. Revzin, "Vospominaniia," in *Iz rabot moskovskogo semioticheskogo kruga*, comp. T. Nikolaeva (Moscow: Iazyki russkoi kul'tury, 1997), p. 794.

103. Viacheslav Vs. Ivanov and Sebast'ian K. Shaumian, "Lingvisticheskie problemy kibernetiki i strukturnaia lingvistika," in *Kibernetiku—na sluzhbu kommunizmu*, volume 1, ed. Berg, p. 231.

104. Viacheslav Vs. Ivanov, "Lingvistika i issledovanie afazii," in *Strukturno-tipologicheskie issledovaniia*, ed. T. Moloshnaia (Moscow: AN SSSR, 1962), p. 93.

105. Ivanov and Shaumian, "Lingvisticheskie problemy kibernetiki," p. 232.

106. Ibid., p. 220.

107. Ibid., p. 218.

108. Aleksei A. Liapunov, "O zadachakh matematicheskoi lingvistiki" (1971), in Liapunov, *Problemy teoreticheskoi i prikladnoi kibernetiki*, p. 202.

109. Revzin, *Sovremennaia strukturnaia lingvistika*, p. 16.

110. See Igor' A. Mel'chuk, "Vsesoiuznoe soveshchanie po matematicheskoi lingvistike," *Mashinnyi perevod i prikladnaia lingvistika* 3 (1959), p. 84.

111. Isaak I. Revzin, *Models of Language* (Methuen, 1966), p. 3.

112. Viacheslav Vs. Ivanov, "Goluboi zver' (Vospominaniia)," *Zvezda* 1995, no. 2, p. 207.

113. Ivanov and Shaumian, "Lingvisticheskie problemy kibernetiki," p. 232.

114. Sebast'ian K. Shaumian, "O sushchnosti strukturnoi lingvistiki," *Voprosy iazykoznaniia* 1956, no. 5, p. 44.

115. Revzin, *Models of Language*, p. 150.

116. Isaak I. Revzin, "Formal'naia teoriia predlozheniia," in *Tezisy konferentsii po mashinnomu perevodu (15–21 maia 1958 g.)* (Moscow, 1958), p. 50.

117. Andrei N. Kolmogorov, "Intervention at the Session" (1956), in *Selected Works of A. N. Kolmogorov*, volume III, ed. A. Shiryayev (Kluwer, 1993), p. 32.

118. Igor' A. Mel'chuk, *Opyt teorii lingvisticheskikh modelei "Smysl—Tekst"* (Moscow: Nauka, 1974), pp. 20, 21. See also Aleksei V. Gladkii and Igor' A. Mel'chuk, *Elementy matematicheskoi lingvistiki* (Moscow: Nauka, 1969), pp. 9–11.

119. Dmitrii Iu. Panov, "Perevod s odnogo iazyka na drugoi pri pomoshchi mashiny: Otchet o pervom uspeshnom ispytanii," *Matematika: Referativnyi zhurnal* 1954, no. 10: 75–76. See N. Macdonald, "Language Translation by Machine—A Report of the First Successful Trial," *Computers and Automation* 3 (1954), no. 2: 6–10.

120. For an overview of early Soviet work on machine translation, see W. John Hutchins, ed., *Machine Translation: Past, Present, Future* (Ellis Horwood, 1986), pp. 132–141.

121. Jurij N. Marčuk, "Machine Translation: Early Years in the USSR," in *Early Years in Machine Translation: Memoirs and Biographies of Pioneers*, ed. W. Hutchins (John Benjamins, 2000), p. 244.

122. Dmitrii Iu. Panov, Aleksei A. Liapunov, and I. S. Mukhin, "Avtomatizatsiia perevoda s odnogo iazyka na drugoi," in *Sessiia Akademii nauk SSSR*, ed. Trapeznikov, p. 194.

123. See Ol'ga S. Kulagina, "A. A. Liapunov i mashinnyi perevod," in *Ocherki istorii informatiki*, ed. Pospelov and Fet; Kulagina, "Pioneering Machine Translation in the Soviet Union," in *Early Years in Machine Translation*, ed.

Hutchins; Igor' Mel'chuk, "Kak nachinalas' matematicheskaia lingvistika," in *Ocherki istorii informatiki*, ed. Pospelov and Fet.

124. Aleksei A. Liapunov, Galina P. Bagrinovskaia, and Ol'ga S. Kulagina, "O nekotorykh metodologicheskikh voprosakh, otnosiashchikhsia k mashinnomu perevodu," in Liapunov, *Problemy teoreticheskoi i prikladnoi kibernetiki*, p. 183.

125. Tat'jana N. Mološnaja, "My Memoirs of Machine Translation in the Soviet Union," in *Early Years in Machine Translation*, ed. Hutchins, p. 228.

126. Igor A. Mel'čuk, "Machine Translation and Formal Linguistics in the USSR," in *Early Years in Machine Translation*, ed. Hutchins, p. 208.

127. Ibid., p. 209.

128. "Reshenie Uchenogo Soveta filologicheskogo fakul'teta MGU," 24 December 1958, as quoted in Ivanov, "Goluboi zver'," no. 3, p. 160.

129. Mel'čuk, "Machine Translation and Formal Linguistics," p. 211.

130. Ivanov, "Goluboi zver'," no. 3, p. 166.

131. Marčuk, "Machine Translation: Early Years in the USSR," p. 250.

132. Ol'ga Sergeevna Kulagina, interview with S. Gerovitch, Moscow, 3 July 1997.

133. "There were few able programmers [at the institute], and they were hard to obtain for our tasks," Ivanov has recalled ("Goluboi zver'," no. 3, p. 167).

134. Revzin, "Vospominaniia," p. 815.

135. A. E. Kibrik and A. I. Koval', "Voprosy prikladnogo iazykoznaniia v sbornike 'Nauchno-tekhnicheskaia informatsiia,'" *Voprosy iazykoznaniia* 1965, no. 5, p. 127.

136. Georgii E. Vleduts et al., "Semiotika," in *Kibernetiku—na sluzhbu kommunizmu*, volume 5, ed. A. Berg (Moscow: Energiia, 1967), p. 390.

137. Viacheslav Vs. Ivanov, "Nekotorye problemy sovremennoi lingvistiki," *Narody Azii i Afriki* 1963, no. 4, p. 159.

138. M. I. Steblin-Kamenskii, "Znachenie mashinnogo perevoda dlia iazykoznaniia," in *Tezisy konferentsii po mashinnomu perevodu*, p. 23. See also Steblin-Kamenskii, "Znachenie mashinnogo perevoda dlia iazykoznaniia," in *Materialy po mashinnomu perevodu* 1 (Leningrad University, 1958), pp. 3–9.

139. Aleksandr E. Kibrik, "Iz istorii sovetskogo iazykoznaniia 60-kh—70-kh godov (o nashikh dostizheniiakh i poteriakh)," in *Le mot, les mots, les bons mots*, ed. A. Clas (Presses de l'Université de Montréal, 1992), p. 17.

140. Igor' A. Mel'chuk, "O terminakh 'ustoichivost'' i 'idiomatichnost',''" *Voprosy iazykoznaniia* 1960, no. 4, p. 78. Melčuk has continued to apply the same rigorous approach to linguistic definitions throughout his career. His lifework, *Cours de Morphologie Générale*, in 5 volumes, contains over 2,000 formal definitions of basic linguistic concepts.

141. Igor' A. Mel'chuk, Review of *Avtomatizatsiia v lingvistike*, ed. L. Zasorina, *Voprosy iazykoznaniia* 1968, no. 1, p. 141.

142. Mel'chuk, "Kak nachinalas' matematicheskaia lingvistika," p. 363.

143. Aleksandr K. Zholkovskii and Igor' A. Mel'chuk, "K postroeniiu deistvuiushchei modeli iazyka ('Smysl-Tekst')," in *Sign. Language. Culture*, ed. A. Greimas et al. (Mouton, 1970), p. 159.

144. On the evolution of the Meaning—Text model, see Iurii D. Apresian, *Izbrannye trudy*, volume I: *Leksicheskaia semantika* (Moscow: Iazyki russkoi kul'tury, 1995), pp. 36–55.

145. Aleksandr K. Zholkovskii and Igor' A. Mel'chuk, "O semanticheskom sinteze," *Problemy kibernetiki* 19 (1967), p. 181.

146. In 1966 at a seminar on machine translation at the Department of Mathematics and Mechanics of Moscow University, Mel'čuk reportedly said, "I am not interested in machine translation at all. I want to understand how people really speak and to build a formal model of human language"; Vladimir Mikhailovich Alpatov, letter to S. Gerovitch, 27–29 July 1998.

147. See Mel'chuk, *Opyt teorii*, esp. pp. 23, 31, 72–73. The concept of "semantic axioms" came from Rudolf Carnap's book *Meaning and Necessity: A Study in Semantics and Modal Logic* (University of Chicago Press, 1958), which was published in Russian in 1959 (Alexander Zholkovsky, letter to S. Gerovitch, 13 August 1998).

148. Igor' A. Mel'čuk, *Cybernetics and Linguistics: Some Reasons for as Well as Some Consequences of Bringing Them Together* (Vienna: Osterr. Studienges. f. Kybernetik, 1977), p. 15.

149. Aleksandr K. Zholkovskii, N. N. Leont'eva, and Iurii S. Martem'ianov, "O printsipial'nom ispol'zovanii smysla pri mashinnom perevode," *Mashinnyi perevod: Trudy ITMiVT* 2 (1961): 17–46. See also the engire volume of *Mashinnyi perevod i prikladnaia lingvistika* 8 (1964).

150. Zholkovskii and Mel'chuk, "O semanticheskom sinteze," p. 177.

151. Claude E. Shannon, "The Redundancy of English," in *Cybernetics: Transactions of the 7th Macy Conference* (New York, 1951), p. 157. For Jakobson's discussion, see Roman Jakobson, "Linguistics and Communication Theory" (1960), in Jakobson, *On Language*, ed. Waugh and Monville-Burston, p. 496.

152. Mel'chuk, *Opyt teorii*, p. 10.

153. Ibid., p. 12.

154. Ibid.

155. See Viacheslav Vs. Ivanov, "Akademik A. I. Berg i razvitie rabot po strukturnoi lingvistike i semiotike v SSSR," in *Ocherki istorii informatiki*, ed. Pospelov and Fet.

156. See Viktor P. Grigor'ev, "O razvitii strukturnykh i matematicheskikh metodov issledovaniia iazyka," *Voprosy iazykoznaniia* 1960, no. 4: 153–155.

157. B. I. Finikov, "O rabote partiinoi gruppy otdelov kibernetiki i programmirovaniia," 11 February 1960 (TsAODM, f. 8033, op. 1, d. 7, l. 128).

158. Protokol partiinogo sobraniia Otdeleniia prikladnoi matematiki, 30 November 1961 (TsAODM, f. 8033, op. 1, d. 8, l. 195).

159. "Predlozheniia po sozdaniiu Instituta kibernetiki Akademii nauk SSSR," in *Ocherki istorii informatiki*, ed. Pospelov and Fet, p. 168.

160. "Protokol soveshchaniia po organizatsii v sostave Otdeleniia fiziko-matematicheskikh nauk AN SSSR instituta s kiberneticheskoi tematikoi" (1960), in *Ocherki istorii informatiki*, ed. Pospelov and Fet, p. 165.

161. Aleksei A. Liapunov, "Soobrazheniia po sostavu Instituta kibernetiki" (ARAN, f. 1875, sdatochnaia op. 2, d. 196, no. 2718).

162. Igor' A. Poletaev, "Otzyv na proekt tematiki Instituta kibernetiki (A. A. Liapunova)" (1961), in *Ocherki istorii informatiki*, ed. Pospelov and Fet.

163. Adapted from "Struktura Instituta kibernetiki AN SSSR," in *Ocherki istorii informatiki*, ed. Pospelov and Fet, p. 179.

164. "Protokol soveshchaniia," p. 167.

165. Quoted in S. I. Samoilenko, "A. I. Berg i razvitie kibernetiki v Sovetskom Soiuze," in *Put' v bol'shuiu nauku*, ed. Siforov, p. 139.

166. Ibid., p. 138.

167. Ivanov, "Goluboi zver'," no. 3, p. 167.

168. See *Ocherki istorii informatiki*, ed. Pospelov and Fet, pp. 180–182.

169. On Akademgorodok, see Paul R. Josephson, *New Atlantis Revisited: Akademgorodok, the Siberian City of Science* (Princeton University Press, 1997).

170. In 1983 the Academy established the Institute of the Problems of Cybernetics in Moscow; this institute, however, has a very narrow scope of research, focusing solely on computing.

171. Samoilenko, "A. I. Berg," pp. 140–141.

172. Vladimir A. Uspenskii, "Serebrianyi vek," p. 300.

173. Ivanov, "Akademik A. I. Berg," pp. 267–268.

174. Sergei L. Sobolev, Anatolii I. Kitov, and Aleksei A. Liapunov, "Osnovnye cherty kibernetiki," *Voprosy filosofii* 1955, no. 4, p. 136.

175. S. L. Sobolev and A. A. Liapunov, "Kibernetika i estestvoznanie," *Voprosy filosofii* 1958, no. 5, p. 127.

176. Sobolev and Liapunov, "Kibernetika i estestvoznanie," in *Filosofskie problemy*, ed. Fedoseev, p. 239.

177. Keldysh, Liapunov, and Shura-Bura, "Matematicheskie voprosy teorii schetnykh mashin," pp. 127–128.

178. Kolmogorov, "Intervention at the Session," p. 31.

179. Al'bert N. Shiriaev, ed., *Kolmogorov v vospominaniiakh* (Moscow: Nauka, 1993), p. 707.

180. Andrei N. Kolmogorov, "Kibernetika," in *Bol'shaia Sovetskaia entsiklopediia*, second edition, volume 51 (1958), p. 149.

181. Andrei N. Kolmogorov, "Informatsiia," in *Bol'shaia Sovetskaia entsiklopediia*, second edition, volume 51 (1958), p. 129.

182. Andrei A. Markov, "Chto takoe kibernetika?" in *Kibernetika. Myshlenie. Zhizn'*, ed. A. Berg et al. (Moscow: Mysl', 1964), p. 41.

183. Ibid., p. 49.

184. Liapunov and Iablonskii, "Teoreticheskie problemy kibernetiki," p. 72.

185. On the parallels between Liapunov's methodology in cybernetics and his work in descriptive set theory, see Iurii I. Zhuravlev, "A. A. Liapunov i stanovlenie kibernetiki v nashei strane," in Liapunov, *Problemy teoreticheskoi i prikladnoi kibernetiki*, p. 5.

186. Bernshtein, "Methods for Developing Physiology," p. 442.

187. Liapunov and Iablonskii, "Teoreticheskie problemy kibernetiki," p. 71.

188. Aleksei A. Liapunov, "Mesto kibernetiki sredi drugikh nauk i ee zadachi" (1971), in Liapunov, *Problemy teoreticheskoi i prikladnoi kibernetiki*, p. 319.

189. Sergei V. Iablonskii, "Teoriia upravliaiushchikh sistem," 1962 (ARAN, f. 1807, op. 1, d. 19, l. 19).

190. Kolmogorov to Uspenskii, 29 December 1964, *Novoe literaturnoe obozrenie* 24 (1997), p. 243.

191. Igor' A. Poletaev, "O matematicheskom modelirovanii," *Problemy kibernetiki* 27 (1973), p. 147.

192. Igor' A. Poletaev, "K opredeleniiu poniatiia 'informatsiia'," in *Issledovaniia po kibernetike*, ed. A. Liapunov (Moscow: Sovetskoe radio, 1970), p. 212.

193. Sobolev and Liapunov, "Kibernetika i estestvoznanie," in *Filosofskie problemy*, ed. Fedoseev, p. 237.

194. Aksel' I. Berg, "Nauka velichaishikh vozmozhnostei" (1962), in Berg, *Izbrannye trudy*, volume II, p. 142.

Notes to Chapter 6

1. Aleksei A. Liapunov and Anatolii I. Kitov, "Kibernetika v tekhnike i ekonomike," *Voprosy filosofii* 1961, no. 9, p. 88.

2. See, e.g., Materialist (pseudonym), "Komu sluzhit kibernetika," *Voprosy filosofii* 1953, no. 5, p. 217; Bernard E. Bykhovskii, "Kibernetika—amerikanskaia lzhenauka," *Priroda* 1952, no. 7, p. 127.

3. See Norbert Viner (Wiener), *Kibernetika, ili Upravlenie i sviaz' v zhivotnom i mashine*, second edition (Moscow: Sovetskoe radio, 1968).

4. See Ol'ga S. Akhmanova, ed., *Russian-English Dictionary*, 15th edition (Moscow: Russkii iazyk, 1991), pp. 250, 668.

5. Compare a comment made by Wade Holland, the editor of *Soviet Cybernetics: Recent News Items*: "The Russian word normally used for control (*upravlenie*), is often more accurately rendered as *management*. Thus, although most translations carry it exclusively as 'control,' it often means control only in a management sense, and not direct, real-time, process control with sensors, actuating mechanisms, feedback, etc. The Russian word *kontrol'* should be translated as 'monitoring,' especially

when applied in the industrial sphere; in this sense, a 'monitoring system' implies no feedback of control commands to actuating mechanisms, and usually simply involves display of monitored values (normally with no computer intervention)"; see Wade Holland, "Commentary," *Soviet Cybernetics: Recent News Items* 3 (1969), no. 4, p. 83.

6. Aksel' I. Berg, "Zadachi kibernetiki v svete reshenii XXII s'ezda KPSS" (1961), in Berg, *Izbrannye trudy*, volume II (Moscow: Energiia, 1964), p. 121.

7. Aksel' I. Berg, "Kibernetika i nauchno-tekhnicheskii progress," in *Biologicheskie aspekty kibernetiki*, ed. A. Kuzin (Moscow: AN SSSR, 1962), p. 18.

8. Aksel' I. Berg, "Osnovnye voprosy kibernetiki" (1959), in Berg, *Izbrannye trudy*, volume II, p. 37.

9. See Viner, *Kibernetika,* pp. 56–57 (editor's footnote). In *Amper i kibernetika* [*Ampère and Cybernetics*] (Moscow: Sovetskoe radio, 1977), Povarev further elaborated this vision of cybernetics as a political science.

10. Murray Eden has translated a relevant passage from Ampère as follows: "Only by intensive study and comparison of the various elements that, for each choice, are provided by a knowledge of all that is relevant to the nation—its character, customs, opinions, history, religion, way of life and property, institutions, and laws—can government create the general rules of conduct that must guide it in regard to each particular case. Therefore, it is only after all the sciences that are concerned with these various factors that one must place the science in question here. I would call this science *cybernetics*. . . . From the restricted definition for the art of steering a vessel, cybernetics took on a meaning—even among the Greeks—of the art of steering in general"; see Murray Eden, "Cybernetics," in *The Study of Information*, ed. F. Machlup and U. Mansfield (Wiley, 1983), p. 409.

11. Quoted in Aksel' I. Berg, "Problemy upravleniia i kibernetika" (1961), in Berg, *Izbrannye trudy*, volume II, p. 72.

12. Gennadii G. Vorob'ev, "A. I. Berg i sotsial'naia kibernetika," in *Put' v bol'shuiu nauku: akademik Aksel' Berg*, ed. V. Siforov (Moscow: Nauka, 1988), p. 227.

13. Quoted in Boris V. Gnedenko, "Otstaivaia issledovatel'skii poisk," in *Put' v bol'shuiu nauku*, ed. Siforov, p. 147.

14. Stenogramma Iubileinoi sessii Nauchnogo Soveta po kompleksnoi probleme "Kibernetika," 12 December 1967 (ARAN, f. 1807, op. 1, d. 134, ll. 210–211).

15. "Otchet o deiatel'nosti Soveta po kibernetike za period s marta po oktiabr' 1961 goda," 1961 (ARAN, f. 1807, op. 1, d. 4, l. 20).

16. The gist of the dash in this title was "must be put."

17. See Aksel' I. Berg, ed., *Kibernetiku—na sluzhbu kommunizmu*, volume 1 (Moscow and Leningrad: Gosenergoizdat, 1961).

18. On the wording of passages on cybernetics in the draft and the final version of the program, see R. David Gillespie, "The Politics of Cybernetics in the Soviet Union," in *Scientists and Public Affairs*, ed. A. Teich (MIT Press, 1974), p. 272.

19. Viktor D. Pekelis, "Chelovek, kibernetika i bog," *Nauka i religiia* 1960, no. 2, p. 27.

20. Berg, “Kibernetika i nauchno-tekhnicheskii progress,” p. 14.

21. Il’ia B. Novik, “Normal’naia lzhenauka,” *Voprosy istorii estestvoznaniia i tekhniki* 1990, no. 4, p. 14.

22. Alexander Vucinich, *Empire of Knowledge: The Academy of Sciences of the USSR (1917–1970)* (University of California Press, 1984), p. 332.

23. Protokol rasshirennogo zasedaniia presidiuma Nauchnogo Soveta po kibernetike Akademii nauk SSSR, 10 January 1962 (ARAN, f. 1807, op. 1, d. 18, ll. 3–4).

24. In 1959, the Academy of Sciences created the Council on Philosophical Problems of Contemporary Natural Science. This Council included the Section on Philosophical Problems of Cybernetics, headed by Aleksandr Spirkin, which functioned simultaneously as the Philosophical Section of the Council on Cybernetics. On the activities of the Philosophical Section, see Aleksandr G. Spirkin, “Rovesnik Sovetskoi vlasti (Vospominaniia),” *Vestnik* 9.2, nos. 12–15 (1997); Boris V. Biriukov, “Otrazhenie sud’by Rossii: K stoletiiu so dnia rozhdeniia A. I. Berga,” *Voprosy filosofii* 1993, no. 10: 152–168; Novik, “Normal’naia lzhenauka.”

25. Wiener, *Cybernetics*, p. 132.

26. Vasilii V. Parin et al., eds., *Problemy kibernetiki: Nekotorye itogi i problemy filosofsko-metodologicheskikh issledovanii* (Moscow: Znanie, 1969), p. 45.

27. Il’ia B. Novik, “O nekotorykh metodologicheskikh problemakh kibernetiki,” in *Kibernetiku—na sluzhbu kommunizmu*, volume 1, ed. Berg, p. 41.

28. Il’ia B. Novik, *Kibernetika: filosofskie i sotsiologicheskie problemy* (Moscow: Gospolitizdat, 1963), p. 80.

29. Boris V. Biriukov and Viktor S. Tiukhtin, “O filosofskoi problematike kibernetiki,” in *Kibernetika. Myshlenie. Zhizn’*, ed. Berg et al., p. 79.

30. Ibid., p. 97.

31. Ibid., pp. 87–92.

32. Pekelis, “Chelovek, kibernetika i bog,” p. 29.

33. Lev P. Teplov, “Vysshii razum,” *Komsomol’skaia pravda* (March 1963).

34. See Iu. G. Antonomov and V. S. Kazakovtsev, *Kibernetika—antireligiia* (Moscow: Sovetskaia Rossiia, 1964); Arkadii D. Ursul, *Teoriia informatsii i religiia* (Moscow: Znanie, 1968).

35. Remarks by Andrei Markov Jr., Dmitrii Gorskii, and Lev Bazhenov in Protokol zasedaniia sektsii filosofii Soveta po kibernetike, 24 March 1962 (ARAN, f. 1807, op. 1, d. 23, ll. 3–4).

36. Aksel’ Berg et al., “Kibernetika,” in *Filosofskaia entsiklopediia*, volume II (1962), p. 505.

37. See N. A. Romanov, “O vozmozhnosti kontakta mezhdu teoriei veroiatnostei i ucheniem akademika I. P. Pavlova ob uslovnykh refleksakh,” *Doklady Akademii nauk SSSR* 1 (1935), no. 4: 193–200.

38. Iurii P. Frolov, “Dialektika zhivoi prirody i sovremennaia kibernetika,” in *Filosofskie voprosy kibernetiki*, ed. V. Il’in et al. (Moscow: Izdatel’stvo sotsial’no-ekonomicheskoi literatury, 1961), p. 314.

39. "Otchet Soveta po kibernetike za 1966 god" [1966] (ARAN, f. 1807, op. 1, d. 93, l. 4).

40. Stenogramma Iubileinoi sessii Nauchnogo Soveta po kompleksnoi probleme "Kibernetika," 12 December 1967 (ARAN, f. 1807, op. 1, d. 134, l. 211).

41. Protokol rasshirennogo zasedaniia biuro Soveta po kibernetike, 5 July 1962 (ARAN, f. 1807, op. 1, d. 18, l. 49).

42. Ibid., ll. 46–47.

43. Iablonskii to Liapunov, 12 July 1962; Liapunov papers.

44. Iulii A. Shreider, "A. A. Liapunov—lider kibernetiki kak nauchnogo dvizheniia," in *Ocherki istorii informatiki*, ed. Pospelov and Fet, p. 205.

45. Anatolii I. Kitov, "Kibernetika i upravlenie narodnym khoziaistvom," in *Kibernetiku—na sluzhbu kommunizmu*, volume 1, ed. Berg, p. 207.

46. Anatolii I. Kitov, "Chelovek, kotoryi vynes kibernetiku iz sekretnoi biblioteki" (interview), *Komp'iuterra* 1996, no. 43, 18 November, p. 44.

47. Aksel' Berg, Anatolii Kitov, and Aleksei Liapunov, "Radioelektroniku—na sluzhbu upravleniiu narodnym khoziaistvom," *Kommunist* 1960, no. 9, pp. 22–23.

48. Aleksei A. Liapunov, "Predislovie," in D. Blekuell and M. A. Girshik (Blackwell and Girshick), *Teoriia igr i statisticheskikh reshenii* (Moscow: Izdatel'stvo inostrannoi literatury, 1958), p. 6.

49. Vladimir A. Abchuk et al., eds., *Vvedenie v teoriiu vyrabotki reshenii* (Moscow: Voenizdat, 1972), p. 310.

50. "27 TsNII—stareishaia nauchnaia organizatsiia Ministerstva oborony," *Chelovek i komp'iuter* 1996, no. 21–22, p. 4. On Soviet "military cybernetics," see David Holloway, *Technology, Management and the Soviet Military Establishment*, Adelphi paper no. 76 (London: Institute for Strategic Studies, 1971).

51. Abchuk et al.,*Vvedenie v teoriiu*, p. 314.

52. Kitov, "Chelovek, kotoryi vynes kibernetiku," p. 45.

53. Aleksei A. Liapunov, "O roli matematiki v sovremennoi chelovecheskoi kul'ture" (1968), in Liapunov, *Problemy teoreticheskoi i prikladnoi kibernetiki*, ed. S. Sobolev (Moscow: Nauka, 1980), p. 305.

54. Nesmeianov and Topchiev to presidium of Central Committee, 14 December 1957 (RGANI, f. 5, op. 35, d. 70, l. 119).

55. G. Telyatnikov, "Cybernetics and the Theory of Troop Control," *Soviet Cybernetics: Recent News Items* 13 (1968), p. 28.

56. Andrei I. Poletaev, "'Voennaia' kibernetika, ili Fragment istorii otechestvennoi 'lzhenauki,'" in *Ocherki istorii informatiki*, ed. Pospelov and Fet, p. 524. See also Kitov, "Chelovek, kotoryi vynes kibernetiku," pp. 44–45.

57. See "27 TsNII—stareishaia nauchnaia organizatsiia."

58. See Boris N. Malinovskii, *Akademik V. Glushkov: Stranitsy zhizni i tvorchestva* (Kiev: Naukova dumka, 1993), pp. 83–84.

59. Viktor Glushkov, "The Art of Control and the Computer," *Soviet Cybernetics: Recent News Items* 6 (July 1967), p. 55.

60. Viktor D. Belkin, "Kibernetika i ekonomika," in *Kibernetiku—na sluzhbu kommunizmu*, ed. Berg, volume 1, p. 191.

61. Mikhail G. Gaaze-Rapoport, "O stanovlenii kibernetiki v SSSR," in *Ocherki istorii informatiki*, ed. Pospelov and Fet, p. 247.

62. Mark R. Beissinger, *Scientific Management, Socialist Discipline, and Soviet Power* (Harvard University Press, 1988), p. 165.

63. Aksel' I. Berg, "Ekonomicheskaia kibernetika: vchera i segodnia," *Voprosy ekonomiki* 1967, no. 12, p. 148.

64. Iosif V. Stalin, *Voprosy leninizma*, 11th edition (Moscow: Gospolitizdat, 1951), p. 326. For a useful historical survey of the use of mathematics in Soviet economics, see Michael Ellman, *Planning Problems in the USSR: The Contribution of Mathematical Economics to Their Solution, 1960–1971* (Cambridge University Press, 1973), pp. 1–17.

65. Leonid V. Kantorovich, "Moi put' v nauke (fragmenty)" (1987), in *Ocherki istorii informatiki*, ed. Pospelov and Fet, p. 420. In 1975, Kantorovich was awarded the Nobel Prize in economics. On his life and work, see N. S. Dvortsina and I. A. Makhrova, comps., *Leonid Vital'evich Kantorovich: Materialy k biobibliografii* (Moscow: Nauka, 1989); *Ocherki istorii informatiki*, ed. Pospelov and Fet, pp. 417–462, 512–514. On the history of linear programming in the Soviet Union, see Al'bert L. Vainshtein, "Vozniknovenie i razvitie primeneniia lineinogo programmirovaniia v SSSR," in *Ekonomiko-matematicheskie metody*, volume 3, ed. L. Mints (Moscow: Nauka, 1966).

66. On Soviet "economic cybernetics," see Beissinger, *Scientific Management*; Martin Cave, *Computers and Economic Planning: The Soviet Experience* (Cambridge University Press, 1980); Ellman, *Planning Problems in the USSR*; John P. Hardt et al., eds., *Mathematics and Computers in Soviet Economic Planning* (Yale University Press, 1967); Richard W. Judy, "The Economists," in *Interest Groups in Soviet Politics*, ed. H. Skilling and F. Griffiths (Princeton University Press, 1971). For a vast bibliography of Russian sources, see Ellman, *Planning Problems in the USSR*, pp. 191–208.

67. "Otchet delegatsii Akademii nauk SSSR o poezdke v Angliiu i SShA," 1962 (ARAN, f. 395, op. 17, d. 39, ll. 58–59). The delegation included director of the Institute of Automation and Remote Control Vadim A. Trapeznikov (head), Aleksandr M. Letov, and Boris N. Naumov. They attended a meeting of the executive committee of the International Federation of Automatic Control in England and visited the Case Institute of Technology and Purdue University in the United States. Letov and Naumov had already visited the US before, met with Wiener, corresponded with him, and helped arrange his visit to the Soviet Union in summer 1960; see Wiener Papers, MIT MC22, boxes 18–20.

68. Nikita S. Khrushchev, *Razvitie ekonomiki SSSR i partiinoe rukovodstvo narodnym khoziaistvom: doklad na Plenume TsK KPSS 19 noiabria 1962 goda* (Moscow: Politizdat, 1962), p. 33.

69. Malinovskii, *Akademik V. Glushkov*, p. 95.

70. Ibid., p. 99.

71. On CEMI, see Simon Kassel, *Soviet Cybernetics Research: A Preliminary Study of Organizations and Personalities*, report R-909-ARPA (Santa Monica: Rand Corporation, December 1971); Judith Thornton Leber, "The Central Economic Mathematics Institute," *Soviet Cybernetics Review* 4 (1970), no. 6: 29–32.

72. "O rabote Tsentral'nogo ekonomiko-matematicheskogo instituta," *Vestnik Akademii nauk SSSR* 1964, no. 10: 3–14; see also Kassel, *Soviet Cybernetics Research*, pp. 94–95; Abraham S. Becker, "Comments," in Hardt et al., *Mathematics and Computers*, p. 129.

73. See Richard W. Judy, "Information, Control, and Soviet Economic Management, " in Hardt et al., *Mathematics and Computers*, pp. 38–39.

74. Viktor Glushkov and Nikolai Fedorenko, "Problemy vnedreniia vychislitel'noi tekhniki v narodnoe khoziaistvo," *Voprosy ekonomiki* 1964, no. 7, pp. 87–88.

75. Vsevolod Pugachev, "Voprosy optimal'nogo planirovaniia narodnogo khoziaistva s pomoshch'iu edinoi gosudarstvennoi seti vychislitel'nykh tsentrov," *Voprosy ekonomiki* 1964, no. 7: 93–103.

76. See Iakov P. Gerchuk, *Granitsy primeneniia lineinogo programmirovaniia* (Moscow, 1965); "Ekonomisty i matematiki za 'Kruglym stolom,'" *Voprosy ekonomiki* 1964, no. 9: 63–110.

77. Quoted in Michael Ellman, "Optimal Planning," *Soviet Studies* 20 (1968), no. 1, p. 118.

78. In Western literature, this result is called the basic theorem of welfare economics.

79. Viktor A. Volkonskii, as quoted in Ellman, "Optimal Planning," p. 114.

80. Quoted in Ellman, "Optimal Planning," pp. 115–116.

81. See Boris N. Malinovskii, *Istoriia vychislitel'noi tekhniki v litsakh* (Kiev: Kit, 1995), pp. 192–193.

82. Quoted in Becker, "Comments," p. 133.

83. Leonid V. Kantorovich, "Vystuplenie na obshchem godichnom zasedanii Akademii nauk SSSR 27 marta 1959 g." (1959), in *Ocherki istorii informatiki*, ed. Pospelov and Fet, p. 444.

84. See "Ekonomisty i matematiki za 'Kruglym stolom.'"

85. Malinovskii, *Akademik V. Glushkov*, p. 100.

86. Kitov to Liapunov, 27 October 1968; Liapunov papers.

87. Viktor A. Zalgaller, "Vospominaniia o L. V. Kantoroviche i ob emotsiiakh, sviazannykh s ego ekonomicheskimi rabotami," in *Ocherki istorii informatiki*, ed. Pospelov and Fet, p. 451.

88. Evsei G. Liberman, quoted in Cave, *Computers and Economic Planning*, p. 46.

89. Gavriil K. Popov, *Problemy teorii upravleniia* (Moscow: Ekonomika, 1970), p. 160.

90. See Malinovskii, *Akademik V. Glushkov*, p. 102.

91. See Malinovskii, *Istoriia vychislitel'noi tekhniki*, p. 337.

92. See Beissinger, *Scientific Management*, p. 254.

93. Elena V. Markova, interview with S. Gerovitch, Moscow, 20 July 1996.

94. On the automation of planning and management in the Brezhnev period, see Beissinger, *Scientific Management*, esp. pp. 182–186; Cave, *Computers and Economic Planning*.

95. *Resheniia partii i pravitel'stva po khoziaistvennym voprosam* , volume 4 (Moscow, 1968), pp. 21–27.

96. V. Golovachev, "A Hercules Is Born," *Soviet Cybernetics: Recent News Items* 5 (June 1967), p. 72.

97. Quoted in Ellman, *Planning Problems in the USSR*, p. 15.

98. Kassel, *Soviet Cybernetics Research*, pp. 97–98.

99. Malinovskii, *Akademik V. Glushkov*, p. 104.

100. Gennadii Maksimovich, *Besedy s akademikom V. Glushkovym* (Moscow: Molodaia gvardiia, 1976), p. 56.

101. Ibid., p. 66.

102. Malinovskii, *Akademik V. Glushkov*, p. 105.

103. Ibid., pp. 105–107.

104. Beissinger, *Scientific Management*, pp. 250, 252.

105. "Spravka ob uluchshenii informatsii ob inostrannom nauchnom, nauchno-tekhnicheskom i rukovodiashchem personale" [19 September 1969] (RGANI, f. 5, op. 61, d. 54, ll. 204–206).

106. Viktor G. Afanasyev, *The Scientific Management of Society* (Moscow: Progress, 1971), p. 280.

107. Nikolai P. Fedorenko, "O razrabotke informatsionno-vychislitel'nogo tsentra," 26 September 1969 (RGANI, f. 5, op. 61, d. 54, ll. 210–220).

108. See Viktor G. Afanas'ev, *Nauchnoe upravlenie obshchestvom* (Moscow: Politizdat, 1967); for the English translation, see Viktor G. Afanasyev, *The Scientific Management of Society*.

109. Materialist (pseudonym), "Whom Does Cybernetics Serve?" (1953), *Soviet Cybernetics Review* 4 (1974), no. 2, p. 37.

110. Boris V. Biriukov et al., "Filosofskie voprosy kibernetiki," in *Kibernetiku—na sluzhbu kommunizmu*, volume 5, ed. A. Berg (Moscow: Energiia, 1967), p. 303.

111. See Aksel' I. Berg, "V. I. Lenin i nauchnaia organizatsiia truda," *Pravda* (24 October 1962).

112. Afanasyev, *The Scientific Management of Society*, pp. 123, 125.

113. Ibid., p. 181.

114. David Holloway, "The Political Uses of Scientific Models: The Cybernetic Model of Government in Soviet Social Science," in *The Use of Models in the Social Sciences*, ed. L. Collins (Westview, 1976), p. 119.

115. Ibid., pp. 126–127.

116. Ibid., pp. 125–126.

117. Aleksandr Zinov'ev, *Russkaia sud'ba: Ispoved' otshchepentsa* (Moscow: Tsentrpoligraf, 1999), p. 418.

118. Alexander Zinoviev, *The Yawning Heights* (Random House, 1979), pp. 52–53.

119. Ibid., p. 30.

120. Ibid., p. 301.

121. Ibid.

122. Ibid., pp. 216–217.

123. Zinov'ev, *Russkaia sud'ba*, p. 333.

124. Inga I. Poletaeva, interview with S. Gerovitch, Moscow, 4 July 1997.

125. Quoted in Poletaev, "'Voennaia' kibernetika," p. 530.

126. Izrail' M. Gel'fand, "Leonid Kantorovich i sintez dvukh kul'tur," in *Ocherki istorii informatiki*, ed. Pospelov and Fet, p. 462.

127. Aleksandr S. Esenin-Vol'pin, "Ob antitraditsionnoi (ul'traintuitsionistskoi) programme osnovanii matematiki i estestvenno-nauchnom myshlenii" (1970), in Esenin-Vol'pin, *Filosofiia. Logika. Poeziia. Zashchita prav cheloveka: Izbrannoe* (Moscow: RGGU, 1999), pp. 91–92 (emphasis added).

128. Alexander Shen, "Entrance Examinations to the Mekh-mat," *Mathematical Intelligencer* 16 (1994), no. 4: 6–10; Iakov I. Khurgin, interview with S. Gerovitch, Moscow, 4 July 1996; Il'ia B. Muchnik, interview with S. Gerovitch, Brookline, Massachusetts, 5 May 2001.

129. See "Ministru zdravookhraneniia SSSR, General'nomu Prokuroru SSSR" (1968), in Esenin-Vol'pin, *Filosofiia*, pp. 328–330; Viktor K. Finn, "A. S. Esenin-Vol'pin v VINITI," in ibid., pp. 425–435.

130. Iurii D. Apresian, "Predislovie ko vtoromu izdaniiu," in *Izbrannye trudy*, volume I: *Leksicheskaia semantika* (Moscow: Iazyki russkoi kul'tury, 1995), pp. II–III; ; Igor A. Mel'čuk, "Machine Translation and Formal Linguistics in the USSR," in *Early Years in Machine Translation*, ed. W. Hutchins (John Benjamins, 2000), pp. 221–222.

131. Yurij D. Apresjan, "Igor Mel'čuk: Brushstrokes for a Portrait," in *Le mot, les mots, les bons mots*, ed. A. Clas (Presses de l'Université de Montréal, 1992), p. 2.

132. Mel'čuk, "Machine Translation and Formal Linguistics," p. 215.

133. See Valentin F. Turchin, *The Inertia of Fear and the Scientific Worldview* (Columbia University Press, 1981); Turchin, *The Phenomenon of Science* (Columbia University Press, 1977).

134. See Alexander Lerner, *Change of Heart* (Lerner and Balaban, 1992); Lerner, *Nachala kibernetiki* (Moscow: Nauka, 1967).

135. Mel'čuk to Jakobson, 12 July 1974 (Jakobson papers, MIT MC 72, box 44.17).

136. Igor' Mel'čuk, "An Open Letter to Colleagues," May 1976 (Jakobson papers, MIT MC 72, box 44.17).

137. Mel'čuk to Jakobson, 30 May 1977 (Jakobson papers, MIT MC 72, box 44.17). See also Mel'čuk, "Machine Translation and Formal Linguistics," pp. 222–223.

138. Vladimir A. Uspenskii, "Serebrianyi vek strukturnoi, prikladnoi i matematicheskoi lingvistiki v SSSR i V. Iu. Rozentsveig: Kak eto nachinalos' (zametki ochevidtsa)," in *Ocherki istorii informatiki*, ed. Pospelov and Fet, p. 295.

139. Mel'čuk to Jakobson, 20 June 1977 (Jakobson papers, MIT MC 72, box 44.17).

140. Zinoviev, *The Yawning Heights*, pp. 517–520.

141. Ibid., p. 520.

Notes to Conclusion

1. On the cultural mechanism of carnival, see Mikhail Bakhtin, *Rabelais and His World* (MIT Press, 1968); Viacheslav Vs. Ivanov, "The Semiotic Theory of Carnival as the Inversion of Bipolar Opposites," in Umberto Eco, Viacheslav Vs. Ivanov, and Monica Rector, *Carnival!* (Mouton, 1984).

2. Inga I. Poletaeva, interview with S. Gerovitch, Moscow, 4 July 1997.

3. Aleksandr K. Zholkovskii and Igor' A. Mel'chuk, "O semanticheskom sinteze," *Problemy kibernetiki* 19 (1967), p. 177.

4. Kotkin, *Magnetic Mountain*, pp. 221, 237.

5. Vladimir A. Uspenskii, "Serebrianyi vek strukturnoi, prikladnoi i matematicheskoi lingvistiki v SSSR i V. Iu. Rozentsveig: Kak eto nachinalos' (zametki ochevidtsa)," in *Ocherki istorii informatiki*, ed. Pospelov and Fet, p. 281.

6. Isaak I. Revzin, *Sovremennaia strukturnaia lingvistika: Problemy i metody*, ed. V. Ivanov (Moscow: Nauka, 1977), p. 214.

7. Isaak I. Revzin, "Nekotorye trudnosti pri postroenii semanticheskikh modelei dlia estestvennykh iazykov," in *Simpozium po strukturnomu izucheniiu znakovykh sistem: tezisy dokladov* (Moscow: AN SSSR, 1962), p. 22.

8. Revzin, *Sovremennaia strukturnaia lingvistika*, p. 226.

9. Isaak I. Revzin, "Vospominaniia," in *Iz rabot moskovskogo semioticheskogo kruga*, comp. T. Nikolaeva (Moscow: Iazyki russkoi kul'tury, 1997), p. 804.

10. Susan Buck-Morss, *Dreamworld and Catastrophe: The Passing of Mass Utopia in East and West* (MIT Press, 2000).

11. See Walter A. McDougall, *. . . the Heavens and the Earth: A Political History of the Space Age* (Basic Books, 1985).

12. For complete citations and discussion, see Stuart W. Leslie, "Science and Politics in Cold War America," in *The Politics of Western Science, 1640–1990*, ed. M. Jacob (Humanities Press International, 1994).

13. I. V. Bystrova, "Razvitie voenno-promyshlennogo kompleksa," in *SSSR i kholodnaia voina*, ed. V. Lel'chuk and E. Pivovar (Moscow: Mosgorarkhiv, 1995), p. 162; Nikolai Krementsov, *Stalinist Science* (Princeton University Press, 1997), p. 5.

14. See Daniel Lee Kleinman and Mark Solovey, "Hot Science/Cold War: The National Science Foundation After World War II," *Radical History Review* 1995, no. 63: 110–139.

15. Thomas F. Gieryn, *Cultural Boundaries of Science* (University of Chicago Press, 1999), p. 23.

16. Jessica Wang, *American Science in an Age of Anxiety: Scientists, Anti-communism, and the Cold War* (University of North Carolina Press, 1999), pp. 8–9.

17. See Paul Edwards, *The Closed World: Computers and the Politics of Discourse in Cold War America* (MIT Press, 1996).

18. See Wiener, *The Human Use of Human Beings*.

19. See Valentin F. Turchin, *The Phenomenon of Science* (Columbia University Press, 1977).

20. On the use of operations research, "the systems approach," and other cyber-speak techniques in the West, see *Systems, Experts, and Computers*, ed. A. Hughes and T. Hughes (MIT Press, 2000). On the Soviet adoption of information-management systems, see William K. McHenry and Seymour E. Goodman, "MIS in Soviet Industrial Enterprise: The Limits of Reform from Above," *Communications of the Association for Computing Machinery* 29 (1986), no. 11: 1034–1043.

21. Richard W. Judy, "Information, Control, and Soviet Economic Management," in *Mathematics and Computers in Soviet Economic Planning*, ed. J. Hardt et al. (Yale University Press, 1967), p. 32.

22. Mikhail Heller, *Cogs in the Soviet Wheel: The Formation of Soviet Man* (Collins Harvill, 1988), p. 289.

23. George Orwell, "Politics and the English Language" (1946), in *The Collected Essays, Journalism, and Letters of George Orwell*, ed. S. Orwell and I. Angus, volume 4 (Harcourt, Brace & World, 1968), pp. 132–133.

24. Erich Fromm, "Afterword," in George Orwell, *Nineteen Eighty-Four* (Signet Classic, [1949] 1981), p. 266.

25. See Sherry Turkle, *The Second Self: Computers and the Human Spirit* (Simon & Schuster, 1984).

This Page Intentionally Left Blank

Index

Ackermann, Wilhelm, 11, 12, 31, 36, 48
Adams, Mark, 5, 13, 211
Aeschylus, 300
Afanas'ev, Viktor, 285–287
Agapov, Boris, 120, 122, 126
Aiken, Howard, 73, 84
Aleksandrov, Aleksandr, 34, 35, 165
Ampère, André-Marie, 254
Andronov, Aleksandr, 108
Anokhin, Petr, 109, 121, 122
Anti-Semitism, 19, 46, 289. *See also* Cosmopolitanism
Applied Mathematics Division. *See* Division of Applied Mathematics
Apresian, Iurii, 290
Aristotle, 222
Artobolevskii, Ivan, 222
Artsimovich, Lev, 184
Ashby, W. Ross, 85, 249
Automechanical Institute, 169

Bakhrushin, Sergei, 56
Bar-Hillel, Yehoshua, 89
Bartlett, Frederic, 113, 114, 126, 130
Bateson, Gregory, 85, 89
Bavelas, Alex, 85, 89
Bazilevskii, Iurii, 134, 157
Behavior
  in cybernetics, 87
  feedback and, 61–63, 88, 90, 114
  in psychology, 2
Belkin, Viktor, 268
Bell Telephone Laboratories, 53, 68–70, 74
Belzer, Seymour, 66
Bel'skaia, Izabella, 233, 234
Berg, Aksel', 138, 139, 176, 193, 199, 205–210, 240, 244, 245, 250, 253–258, 261–264, 271, 278, 285
Berg, Raisa, 212, 213, 218
Beria, Lavrentii, 32
Bernshtein, Nikolai, 44–47, 108, 109, 161, 219–226, 249
BESM computer, 131, 134, 136, 137, 140, 141, 148, 149, 157, 160
BESM-2 computer, 141
Bigelow, Julian, 7, 53, 60–63, 75, 84, 85
Bitsadze, Andrei, 175, 188
Bogoliubov, Nikolai, 105
Bongard, Mikhail, 222–224
Borel, Émile, 36
Bosh'ian, Gevorg, 189
Bowker, Geoffrey, 1, 94, 98
Brezhnev, Leonid, 279, 283, 286, 298, 299
Brodsky, Joseph, 293
Brosnin, Henry, 85
Brouwer, L. E. J., 31, 35
Bruk, Isaak, 134, 137, 139, 145, 157, 175, 195, 275, 278
Buck-Morss, Susan, 300
Bukovskii, Vladimir, 2
Bulganin, Nikolai, 140
Bush, Vannevar, 60, 73, 132
Buslenko, Nikolai, 266
Butlerov, Aleksandr, 117
Bystrova, I., 301

Cambridge University, 56, 113, 114
Cannon, Walter, 59
Carnap, Rudolf, 121
Catherine the Great, 296
CEMI. *See* Central Economic Mathematical Institute
Central Committee of Communist Party, 15, 33, 34, 115, 119, 124–126, 139, 147–149, 154, 157–160, 164, 169, 170, 182–185, 214, 245, 256, 264, 267, 271, 272, 279, 280–283
Central Economic Mathematical Institute, 272, 273, 280, 283
Central Statistical Administration, 272, 276
Chief Administration for Computer Technology, 281
Chkhaidze, Levan, 226
Chomsky, Noam, 297
Chumak, 185
Code
 in communication engineering and cryptology, 67, 71, 72
 in cybernetics, 10, 206, 207, 239, 240
 in linguistics, 92, 93, 207, 229, 230
 in molecular biology, 67, 97, 207, 211
 in philosophy, 259
 in physiology, 207, 220, 223
Cold War, 4, 11, 14–19, 38, 39, 54, 112–116, 119, 123, 130, 132, 141, 146–151, 300–303
Communication
 in communication engineering, 2, 7, 10, 67–72
 in cybernetics, 10, 87–91, 196, 239, 240, 246, 248, 262
Computation Center of the Academy of Sciences, 137, 140, 141, 195, 235, 257
Computation Center of the State Planning Committee, 272, 280
Computation Center 1 of the Ministry of Defense, 139, 140, 176, 266, 267
Computers
 as "display technology," 146–151
 gap in production of, 157–160, 193, 194
 military applications of, 48, 49, 54, 104, 120, 123, 129–141, 145, 150, 151, 157, 173, 174, 176, 179, 302
 as symbols of objectivity, 161, 162
Control
 in control engineering, 2, 53, 61–63, 67, 68
 in cybernetics, 10, 53, 87, 90, 178, 179, 225, 246–250, 253, 254, 262
 in economics, 206, 253, 254, 264–281
 in military command, 265–267
 in philosophy, 259
 in physiology, 220, 223, 224, 265
 in politics, 284–288
Control systems, 199, 203, 206, 207, 212, 217, 218, 246, 249, 250, 256, 265, 267, 270, 286, 289
Copernicus, Nicolas, 189
Cosmopolitanism, 19, 23–25, 39, 46, 119, 123, 164. *See also* Anti-Semitism
Council on Cybernetics, 199, 204, 205, 209–214, 218, 226, 240, 241, 245, 254–263, 268, 269, 285
Crick, Francis, 66
CyberNewspeak, 9, 285–288, 299
Cyberspeak, 2, 53, 88, 89
 as carnival language, 293–296
 as Cold War language, 150, 151
 as common language, 8, 89, 90, 97, 202, 214, 217, 225, 229, 230
 as discursive strategy, 9, 221, 295–299
 formation of, 7, 83–89
 as ideological language, 3, 257–260, 291, 292, 295, 296
 as instrument of freedom, 296–300, 303
 interpretations of, 246–251
 as language of negotiation, 298, 299
 as language of truth and objectivity, 161, 162, 227, 231, 260
 as metaphorical language, 53, 88, 89, 219, 224, 303
 as opponent of newspeak, 7, 8, 118–130, 162, 179–183, 227, 231, 232

as part of CyberNewspeak, 9, 285–288, 299
as universal language, 53, 89–96, 155, 202, 253, 254, 260, 289, 296, 300–303

Darwin, Charles, 189, 217
Dashevskii, Lev, 121, 123, 126, 135
Delbrück, Max, 66
De Vries, Hugo, 66
Dialectical materialism, 5, 11, 14, 19, 20, 35, 46, 47, 165, 184, 187, 200, 294, 296, 299
and cybernetics, 127–130, 170–173, 179–183, 197, 202, 213, 257–260
newspeak and, 26–31, 166, 170–173, 190, 191
Differential Analyzer, 73, 132
Discursive strategies, 9, 13, 14, 21, 47
“de-ideologization,” 7, 19, 20, 35, 104, 105, 143, 144, 150, 151
“ideologization,” 7, 18, 19, 163
Division of Applied Mathematics, 134–140, 161, 174, 187, 189, 192, 203, 220, 232–235, 241, 242
Dobrovol’skii, G., 185
Dorodnitsyn, Anatolii, 195, 257, 262
Dubarle, Père, 100
Dubinin, Nikolai, 183
Dudley, Homer, 69
Dvoriankin, Fedor, 186

EDVAC, 79
Edwards, Paul, 54, 302
Efroimson, Vladimir, 243
Egorov, Dmitrii, 169
Einstein, Albert, 190
Energy Institute, 134, 137, 145, 157, 174
Engel’gardt, Vladimir, 213
Engels, Friedrich, 48, 167, 190
ENIAC, 79
Entropy
in communication engineering, 67, 70, 72
in cybernetics, 49, 86–91, 98, 258
in thermodynamics, 2, 64, 65, 67
Epstein, Mikhail, 3, 13, 22, 26
Ermilin, Konstantin, 34
Esenin-Vol’pin, Aleksandr, 288–290

Fedorenko, Nikolai, 272–274
Feedback
in biology, 218
in control engineering, 2, 62, 86, 88, 114, 178
in cybernetics, 10, 53, 55, 86–92, 177
in economics, 270, 275, 302
in physiology, 61–63, 75, 109, 114, 122, 219, 224, 298
in politics, 285, 286
Fet, Iakov, 244, 269
Filin, Fedot, 40
Fischer, R. A., 59
Formalism, 12, 19, 21, 23, 27, 28
in biology, 32, 33, 40, 183, 184, 200
in computing, 48
in engineering, 110
as floating signifier, 7, 31, 48
in linguistics, 37–42, 48, 110, 232
in mathematics, 31–37
in music, 32, 33
in philosophy, 32
Frank, Gleb, 244
Frank, Lawrence, 85
Frege, Gottlob, 31
Frenkel’, Iakov, 169
Frolov, Iurii, 224, 261
Fromm, Erich, 303

Galilei, Galileo, 189
Galison, Peter, 54, 89
Gal’perin, I., 223, 224
Gastev, Alexei, 44, 285
Gavrilov, Mikhail, 110
Gel’fand, Izrail’, 220, 289, 290
Genis, Aleksandr, 154
George, Frank, 97
Gerard, Ralph, 85, 90
Gieryn, Thomas, 301
Gillespie, R. David, 166
Glushkov, Viktor, 267, 268, 271–273, 276–283
Gnedenko, Boris, 243, 262

Goldman, Stanford, 144
Goldstine, Herman, 84
Gorbachev, Mikhail, 278
Gor'kii University, 108
Gosplan. *See* State Planning Committee
Graham, Loren, 5, 128, 191
Grechko, Georgii, 141
Griffith, William, 3
Gutenmakher, Lev, 232

Haraway, Donna, 55
Hartley, Ralph, 68, 70, 91
Harvard University, 56, 91, 113
Haskins Laboratories, 226
Haverford College, 78
Heims, Steve, 55
Heller, Mikhail, 48, 303
Hessen, Boris, 169
Hilbert, David, 11, 12, 31, 32, 35, 36, 48, 58, 74
Hobbes, Thomas, 100
Hoch, Paul, 301
Hodges, Andrew, 74, 75
Holloway, David, 5, 171, 180, 190, 286
Homeostasis
  in cybernetics, 86–89, 95, 99, 219
  in physiology, 2

Iablonskii, Sergei, 203, 243, 248, 249, 262, 289
Ianovskaia, Sof'ia, 11, 36, 48, 288
Iaroshevskii, Mikhail, 121–123, 126, 130, 136, 137
Idealism, 19–21, 27, 28, 30, 31, 48, 142
  in biology, 17, 23, 112, 184, 189, 213
  in chemistry, 117, 189
  in cybernetics, 119–127, 130, 137, 170, 172, 189, 195, 196, 213
  in engineering, 110
  as floating signifier, 7
  in linguistics, 39, 40, 119, 121
  in mathematics, 11, 12, 24, 33–37
  in philosophy, 32, 172, 213, 259
  in physics, 20, 112, 127, 163, 165, 170, 182, 189, 222
  in physiology, 42–47, 220, 222
Ideologemes, 22–25, 47
Ideology
  knowledge and, 17–21
  language and, 3, 21–26, 257–260, 291, 292, 295, 296
  as language of negotiation, 13
  as rationalization of discourse, 47
  ritual and, 115–118
Ilizarov, Simon, 168
Information
  in communication engineering, 2, 53, 54, 68–72, 144
  in cybernetics, 10, 53, 54, 86–92, 98, 177, 178, 196, 203, 206, 207, 214, 239, 240, 246–250, 258, 262, 288, 295
  in genetics, 207, 211–218, 256
  in linguistics, 207, 229, 230
  in economics, 206, 256, 264–266, 272–274, 278, 279, 282, 302
  in philosophy, 258, 259
  in physiology, 207, 219, 220, 223, 225
  in politics, 283–287
  in theology, 259
Institute of Atomic Energy, 137, 176
Institute of Automation and Remote Control, 107–110, 290
Institute of Biophysics, 222
Institute of Communication, 205
Institute of Cybernetics (project), 241–245
Institute of Cybernetics (in Kiev), 267, 271, 273
Institute of Electrical Engineering (in Kiev), 133
Institute of Electrical Engineering (in Moscow), 290
Institute of Electronic Control Machines, 145, 268, 275
Institute of Experimental Medicine, 43
Institute of Foreign Languages, 227, 229, 232–235, 241, 296, 298
Institute of Labor, 44, 108
Institute of Linguistics, 241, 242, 291
Institute of Oriental Studies, 241
Institute of Philosophy, 16, 119, 120, 123, 124, 165, 166, 168

Institute of Physical Culture, 108
Institute of Physics and Biophysics, 108
Institute of Precise Mechanics and Computer Technology, 133–136, 139–142, 147, 149, 157, 158, 174, 232–235, 242
Institute of Prosthetics, 46
Institute of Red Professors, 168
Institute of the Russian Language, 241, 242
Institute of Scientific Information (Institute of Scientific and Technical Information), 139, 156, 233, 242, 282
Institute of Semiotics (project), 241–245
Institute of Slavic Studies, 241, 242
Institute of Theoretical Astronomy, 141
Institute for the History of Science and Technology, 169
Institute for Design of Computation Centers and Economic Information Systems, 272
Intuitionism, 31, 35, 56
Iordanskaia, Lidiia, 290
Isaev, 186
ITMVT. *See* Institute of Precise Mechanics and Computer Technology
Ivanov, Viacheslav, 227–236, 240–243

Jakobson, Roman, 37, 38, 85, 91–94, 110, 227, 228, 230, 234, 239, 240, 290, 296
Joravsky, David, 5, 16, 168
Josephson, Paul, 4

Kaganovich, Lazar', 153
Kagarlitsky, Boris, 153
Kalmykov, Valerii, 209
Kammari, Mikhail, 165
Kantorovich, Leonid, 268–270, 275–278
Kapitsa, Petr, 163, 184, 188
Kartsev, Mikhail, 145
Kay, Lily, 95, 97
Keldysh, Mstislav, 140, 143, 187, 209, 245, 271, 272
Keller, Evelyn Fox, 66, 95
Kevles, Daniel, 301
Khar'kov University, 241
Khintchine (Khinchin), Aleksandr, 58
Khrushchev, Nikita, 5, 6, 8, 126, 136, 149, 151, 153, 155, 164, 167, 169, 188, 200, 211, 213, 245, 271, 272, 279, 289, 298, 299
Khurgin, Iakov, 243
Kiev University, 241
Kirilenko, Andrei, 280
Kirillin, Vladimir, 184
Kitov, Anatolii, 139, 173, 176–181, 193, 243, 246, 253, 264, 266, 267, 277, 278
Klüver, Heinrich, 85, 89
Knuniants, Ivan, 213
Kobrinskii, Aron, 222
Kojevnikov, Alexei, 6, 29, 117
Kolbanovskii, Viktor, 126. *See also* "Materialist"
Kolman, Ernest, 23, 32, 60, 167–173, 181, 183, 197, 259, 260, 288
Kolmogorov, Andrei, 7, 23, 24, 55–61, 103–105, 151, 183, 196, 213, 215, 228, 227, 232, 247–250
Konstantinov, Fedor, 125
Korolev, Sergei, 141, 281
Kosygin, Aleksei, 271
Kotkin, Stephen, 6, 24, 295
Kovalev, Sergei, 291
Kraizmer, Leonid, 202, 203
Krementsov, Nikolai, 6, 118, 301
Krylov, Nikolai, 105
Kubie, Lawrence, 85
Kulagina, Ol'ga, 233
Kuperman, Faina, 187
Kurchatov, Igor', 141, 281

Landau, Lev, 153, 169, 184
Lavrent'ev, Mikhail, 133–136, 142, 147, 148, 213, 263
Lazarev, Petr, 108
Lazarsfeld, Paul, 85

Lebedev, Sergei, 131, 133–136, 143, 144, 157, 195
Lee, Dorothy, 85
Leibnitz, Gottfried Wilhelm, 238
Lenin, Vladimir, 21, 24, 27, 37, 127, 167, 192, 254, 285
Leningrad University, 34, 176, 212, 241
Lepeshinskaia, Ol'ga, 189
Lerner, Alexander, 290
Lesechko, Mikhail, 134
Lewin, Kurt, 85
Liapunov, Aleksei, 36, 126, 161, 173–192, 195, 197, 202–206, 209–218, 223, 226, 228–235, 240–250, 253, 258, 262–264, 268, 277, 278, 288, 289
Liapunova, Elena, 183, 185
Liapunova, Natal'ia, 57, 135, 173, 183, 185, 217, 244, 263
Licklider, Joseph C. R., 85
Life
  as chain of balances, 42
  as order, 2, 64–66, 88, 97
  as questionable term, 90
  as subject of cybernetics, 214–218, 224, 250
Liusternik, Lazar', 266, 290
Logicism, 31
Lorente de Nó, Rafael, 85, 89
Lotman, Iurii, 227
Lupanov, Oleg, 289
Lysenko, Trofim, 5, 17–19, 23, 32–34, 40, 45, 59, 60, 104, 111, 112, 116, 118, 164, 183–190, 200, 201, 211, 212, 214, 217, 218

M-1 computer (Automatic Computing Machine), 134, 137, 138, 145
M-2 computer, 137, 139, 145
M-4 computer, 145
M-4M computer, 145, 146
M-5 computer, 145, 275
M-20 computer, 141
M-40 computer, 139
M-50 computer, 139
Mach, Ernst, 12, 24
Maiorov, Fedor, 147
Maistrov, Leonid, 36
Maksimov, Aleksandr, 165
Malenkov, Andrei, 215
Malenkov, Georgii, 153
Malinovskii, Boris, 135, 136, 138, 146, 177
Mandelbrot, Benoit, 94
Mark I computer, 73
Markov, Andrei, Jr., 188, 191, 192, 201, 243–245, 248–250, 257, 258, 290
Markov, Andrei, Sr., 106, 188
Markova, Elena, 278
Marr, Nikolai, 39–41
Marx, Karl, 11, 21, 27, 167, 171, 172, 190, 263
Marxism, 3, 5, 18, 22, 25, 29, 32, 35, 36, 39, 110, 187, 190, 234, 270, 271, 275, 300
Marxism-Leninism, 21, 24, 26, 186, 291, 297
Materialism, 11, 12, 17, 20, 27, 28, 30, 36, 181, 182, 189, 258
Massachusetts Institute of Technology, 58, 72–74, 84
"Materialist" (pseudonym), 125–127, 171. *See also* Kolbanovskii
Mathematical Institute, 14, 103, 161, 174, 176, 188, 191
Matiukhin, Nikolai, 145
McCulloch, Warren, 7, 75–81, 84, 89, 95, 96, 106
McDougall, Walter, 300
Mead, Margaret, 85, 110
"Meaning—Text" linguistic model, 237–240, 290, 291
Mechanical Institute, 147
Mechanicism, 19, 23, 28, 30, 46, 47, 90, 117, 119, 122, 125, 127, 130, 142, 170, 184, 219, 222
Mel'čuk, Igor', 232–240, 243, 290, 291, 294
Mendel, Gregor, 45, 59, 60, 166, 184, 186, 190
Mergelian, Sergei, 209
MESM computer (Small Electronic Calculating Machine), 121, 130, 133–135, 174

Metaphysics, 12, 19, 21, 27, 28, 30, 40, 142
Metaphors, 8, 29, 52, 54, 94, 95, 105, 118
 body as servomechanism, 61–63, 86, 88, 95, 109
 brain as computer, 49, 79–83, 88, 89, 94, 229, 298
 brain as logical machine, 75–79, 86
 computer as brain, 48, 79–83, 88, 89, 94, 97, 143, 150, 178, 182, 219
 chromosome as coded message, 67
 death as disorder, 65, 87, 88
 life as order, 64, 65, 81, 88
 man as information source, 67–72, 86
 man as machine, 43, 44, 48, 51, 53, 69, 79, 86, 104, 127, 128, 142, 150, 219, 224, 225, 259, 260
 mind as logical machine, 74, 75, 79, 172
 nervous system as telephone switchboard, 43, 44, 47, 127, 219
 organism as message, 87
Michurin, Ivan, 17
Military Artillery Engineering Academy, 174, 176
Military Technical Academy, 176
Mindell, David, 54, 69
Ministry of Agriculture, 185
Ministry of Defense, 139, 176, 206, 266
Ministry of Higher Education, 185, 193
Ministry of Machine Building and Instrument Construction, 134, 147–149, 159, 176
Ministry of Metallurgy, 277
Ministry of Radio Industry, 159
Ministry of Supplies, 277
Moloshnaia, Tat'iana, 233, 234
Molotov, Viacheslav, 32, 153
Morgan, T. H., 60, 111, 190
Morris, Charles, 85
Moscow University, 11, 18, 56, 58, 112, 137, 169, 174, 176, 183, 185–187, 227, 228, 233–235, 241, 253, 268, 289, 298
Navy Academy, 205
Nemchinov, Vasilii, 213, 270
Nesmeianov, Aleksandr, 117, 159, 160, 195, 209
Newspeak, 13, 21
 as Cold War language, 13–21, 150, 151
 as discursive strategy, 9, 295, 299
 as ideological language, 21–26
 as language of negotiation, 26, 299
 as opponent of cyberspeak, 7, 8, 118–130, 162, 179–183, 227, 231, 232
 Orwell's concept of, 3, 12, 13
 as part of CyberNewspeak, 9, 285–288, 299
 as philosophical language, 26–31, 166, 170–173, 190, 191
 as universal language, 1, 9
Noble, David, 55
Noise
 in communication engineering, 2, 67–72
 in cybernetics, 86, 87, 91
 in philosophy, 258
NORC (Naval Ordnance Research Calculator), 157
Northrop, Filmer S. C., 85
Novik, Il'ia, 103
Novosibirsk University, 241
Novozhilov, Viktor, 270, 274, 275
Nyquist, Harry, 68

OGAS. *See* Statewide Automated Management System
Oparin, Aleksandr, 111
Orbeli, Leon, 46
Order
 as characteristic of life, 64–66, 88
 in cybernetics, 2, 86–88
 in thermodynamics, 2, 64, 65
Orwell, George, 3, 12, 13, 22, 25, 303

Palm, Günther, 95
Panov, Dmitrii, 139, 140, 149, 158, 233, 234
Parin, Vasilii, 214, 218

Parshin, Petr, 148
Pasternak, Boris, 234
Pauling, Linus, 117
Pavlov, Ivan, 28, 42–47, 63, 105, 108–110, 122, 127, 170, 201, 218, 223, 261
Pearson, Karl, 36
Pechenkin, Aleksandr, 117
Perutz, Max, 66
Pickering, Andy, 54
Pitts, Walter, 7, 75–81, 84, 89, 94–96, 106
Pogrebinskii, Solomon, 135
Poincaré, Henri, 36
Poletaev, Igor', 162, 197, 242, 250, 266, 267, 288, 289, 294
Poletaeva, Inga, 294
Politburo, 15, 281
Popov, Gavriil, 278
Pospelov, Dmitrii, 244, 269
Povarov, Gelii, 254, 288
Prometheus, 300
PROMIN' computer, 283
Proteus, 299

Quastler, Henry, 85

Rashevsky, Nicolas, 76, 77, 106, 110
Ratner, Vadim, 218
Reflex
  in cybernetics, 63, 87
  modeling of, 175, 222, 223, 261
  in physiology, 2, 43–45, 108, 109, 127, 219–223
Revzin, Isaak, 227, 229–231, 235, 296, 297
Riga University, 241
Romanov, N., 261
Romashov, Dmitrii, 183
Rosenblueth, Arturo, 7, 62, 63, 75, 84, 85
Rozental', Mark, 181, 196
Rozentsveig, Viktor, 232
Russell, Bertrand, 31, 56, 121

Sakharov, Andrei, 184, 290, 291
Sakharov, Vladimir, 183
Saussure, Ferdinand de, 37, 92
Schrödinger, Erwin, 7, 64–67, 81, 86, 106, 110–112, 215
Schweber, Sylvan, 301
Sechenov, Ivan, 122
Serenkov, 186
Shannon, Claude, 7, 53, 67–75, 78, 79, 86, 91, 92, 98, 106, 108, 110, 144, 227, 239, 249
Shaumian, Sebast'ian, 229–231, 258, 288
Shestakov, V., 108, 110
Shiriaev, Al'bert, 57
Shkabara, Ekaterina, 121, 123, 126
Shklovskii, Viktor, 37
Shmal'gauzen, Ivan, 217, 218
Shostakovich, Dmitrii, 32
Signal
  in communication engineering, 2, 67–71
  in cybernetics, 10, 87, 91, 178, 239
  in physiology, 62
Sinyavsky, Andrei, 29
Sobolev, Sergei, 137, 164, 173–184, 191, 211–215, 224, 246, 250, 258
Spirkin, Aleksandr, 259
Stalin, Joseph, 5, 6, 15, 17, 20, 25, 27, 30–34, 40, 41, 48, 112, 115, 116, 123, 131, 134, 142, 148, 153, 160, 162, 164, 167, 186, 200, 205, 211, 269, 293, 299
State Planning Committee (Gosplan), 206, 245, 268, 269, 272, 276, 279, 280
Statewide Automated Management System, 281
Steblin-Kamenskii, Mikhail, 236
STRELA computer, 134, 136, 139, 140, 235
Studitskii, Aleksandr, 186
Sukachev, Vladimir, 213
Suslov, Mikhail, 124, 283

Tamm, Igor', 184, 213
Tartu University, 227
Tbilisi University, 241
Terletskii, Iakov, 165

Thom, Françoise, 1
Timoféeff-Ressovsky, Nikolai, 66, 105, 106, 112, 183, 212, 215–217
"Totalitarian model" of Soviet history, 4–6, 115, 116
"Trading zone," 8, 89, 200–204
Trotsky, Leon, 38
Trubetskoi, Nikolai, 38, 39
Tsetlin, Mikhail, 220, 225, 226
Tufts College, 56
Tukey, John, 70
Turchin, Valentin, 290, 302
Turing, Alan, 7, 73–79, 96
Turing machine, 74, 75, 78, 81, 96

URAL computer, 149, 157
United States, 14, 15, 48, 52, 55, 61, 99, 104, 105, 119–121, 125, 127, 130, 132, 138–143, 148, 150, 151, 157–160, 189, 193, 194, 196, 200, 240, 270, 280, 282, 290, 300–303
University of Chicago, 75, 76
University of Illinois, 75, 76
University of Montreal, 291
Uspenskii, Vladimir, 228, 232, 243, 245, 297
Uttley, A. M., 94

Vail', Petr, 154
Vavilov, Sergei, 29
Virchow, Rudolf, 190
Von Förster, Heinz, 85
Von Mises, Richard, 23, 24, 36
Von Neumann, John, 7, 53, 55, 79–84, 89, 95, 96, 225
Vucinich, Alexander, 160, 257

Walker, Rachel, 21, 26
Wallace, Alfred, 114, 130
Wang, Jessica, 301
Watson, James, 66
Weaver, Warren, 7, 53, 54, 79, 91, 239
Wheland, George, 117
Whitehead, Alfred North, 121
Wiener, Norbert, 2, 7, 53–64, 67, 68, 70, 73–79, 83–105, 108, 110, 113, 114, 119–121, 126–130, 144, 145, 151, 170, 173, 174, 177, 179, 193, 196, 199, 200, 209, 220, 222, 227, 244–250, 253, 254, 258, 285, 302
Weismann, August, 190
Wilkins, Maurice, 66

Zavadovskii, Mikhail, 183
Zel'dovich, Iakov, 184
Zhdanov, Andrei, 33
Zhdanov, Iurii, 131, 164, 169
Zhebrak, Anton, 183
Zhirmunskii, Viktor, 38
Zholkovsky, Alexander, 237–239, 290, 294
Zimmer, Karl, 66
Zinov'ev, Aleksandr, 30, 287, 288, 291, 292