1 Cybernetics and Socialism

The more I reflect on these facts, the more I perceive that the evolutionary approach to adaptation in social systems simply will not work any more. . . . It has therefore become clear to me over the years that I am advocating revolution.

—Stafford Beer, Address to the Fifth Annual Conference of the Pierre Teilhard de Chardin Association of Great Britain and Ireland, October 1970

In July 1971, the British cybernetician Stafford Beer received an unexpected letter from Chile. Its contents would dramatically change Beer's life. The writer was a young Chilean engineer named Fernando Flores, who was working for the government of newly elected Socialist president Salvador Allende. Flores wrote that he was familiar with Beer's work in management cybernetics and was "now in a position from which it is possible to implement on a national scale—at which cybernetic thinking becomes a necessity—scientific views on management and organization."[1] Flores asked Beer for advice on how to apply cybernetics to the management of the nationalized sector of the Chilean economy, which was expanding quickly because of Allende's aggressive nationalization policy.

Less than a year earlier, Allende and his leftist coalition, Popular Unity (UP), had secured the presidency and put Chile on a road toward socialist change. Allende's victory resulted from the failure of previous Chilean governments to resolve such problems as economic dependency, economic inequality, and social inequality using less drastic means. His platform made the nationalization of major industries a top priority, an effort Allende later referred to as "the first step toward the making of structural changes."[2] The nationalization effort would not only transfer foreign-owned and privately owned industries to the Chilean people, it would "abolish the pillars propping up that minority that has always condemned our country to underdevelopment," as Allende referred to the industrial monopolies controlled by a handful of Chilean families.[3] The majority of parties in the UP coalition believed that by changing Chile's economic base, they would subsequently be able to bring about institutional and ideological change within the nation's established legal framework, a facet that set Chile's path to socialism apart from that of other socialist nations, such as Cuba or the Soviet Union.[4] Flores worked for the Chilean State Development Corporation, the agency responsible for leading the nationalization effort. Although Flores was only twenty-eight when he wrote Beer, he held the third-highest position in the development agency and a leadership role in the Chilean nationalization process.

Beer found the Chilean invitation irresistible. Flores was offering him a chance to apply his ideas on management on a national level and during a moment of political transformation. Beer decided he wanted to do more than simply offer advice, and his response to Flores was understandably enthusiastic. “Believe me, I would surrender any of my retainer contracts I now have for the chance of working on this,” Beer wrote. “That is because I believe your country is really going to do it.”[5] Four months later, the cybernetician arrived in Chile to serve as a management consultant to the Chilean government.

This connection between a Chilean technologist working for a socialist government and a British consultant specializing in management cybernetics would lead to Project Cybersyn, an ambitious effort to create a computer system to manage the Chilean national economy in close to real time using technologies that, in most cases, were not cutting edge. Such a connection between British cybernetics and Chilean socialism was rather unusual, not only because of their geographical separation but also because they represented very specific strains of scientific or political thought. As I argue in this chapter, Beer and Flores joined forces in part because Beer and Popular Unity were exploring similar intellectual terrain in the different domains of science and politics.

Beer’s writings on management cybernetics differed from the contemporaneous work taking place in the U.S. military and think tanks such as RAND that led to the development of computer systems for top-down command and control. From the 1950s onward, Beer had drawn from his understanding of the human nervous system to propose a form of management that allowed businesses to adapt quickly to a changing environment. A major theme in Beer’s writings was finding a balance between centralized and decentralized control, and in particular how to ensure the stability of the entire firm without sacrificing the autonomy of its component parts.

Similarly, the Popular Unity government confronted the challenge of how to implement substantial social, political, and economic changes without sacrificing Chile’s preexisting constitutional framework of democracy. A distinguishing feature of Chile’s socialist process was the determination to expand the reach of the state without sacrificing the nation’s existing civil liberties and democratic institutions. Both Beer and Popular Unity were thus deeply interested in ways of maintaining organizational stability in the context of change and finding a balance between autonomy and cohesion.

For Beer and the Popular Unity government, these were not simply questions of intellectual interest; they also shaped practice. Beer applied his understanding of adaptive control to improve industrial management in areas ranging from steel production to publishing. In the Chilean context, understandings of democratic socialism shaped the relationships among the executive, legislative, and judicial branches of government and influenced economic policy. These conceptual commonalities, combined with the emphasis both Beer and Popular Unity put on translating these ideas into action, led Flores to contact Beer and motivated Beer to accept Flores's consulting invitation.

Beer occupies a central role in this chapter and in this book as a whole. Some of the key ideas in his cybernetic writings before his first trip to Chile in 1971 show the correspondence between his cybernetics and Chilean socialism. Nevertheless, it is important to recognize that Beer was only one person in a highly collaborative transnational team. He may have come to Chile thinking that he would bring the ideas he formed in Britain to Latin America and apply them in a developing world context. However, readers should keep in mind that Beer's work in Chile, and with members of the Chilean government, transformed him personally, enriched his thinking on cybernetics and government, and took his work and life in new directions.

Understanding Beer's ideas at the outset of his Chilean collaboration is key to understanding the eventual design of Project Cybersyn and why its designers believed the design was consistent with the values of Chilean socialism, which I discuss in subsequent chapters. This brief analysis of management cybernetics will also make clear why Flores viewed Beer's work as potentially beneficial to the Chilean road to socialism. This chapter introduces the reader to the interdisciplinary postwar science of cybernetics and contextualizes Beer's work in the field. Most important, the chapter argues that the synergy between Beer (cybernetics) and Flores (politics) was based on a mutual understanding of core problems in the history of both areas. Specifically, how do you create a system that can maintain its organizational stability while facilitating dramatic change, and how do you safeguard the cohesion of the whole without sacrificing the autonomy of its parts?

Stafford Beer

The history of cybernetics is filled with curious characters, and Stafford Beer was not an exception. He wore a long beard for much of his life, habitually smoked cigars, and drank whiskey from a hip flask while discussing scientific ideas late into the night. He included his own poetry and drawings in his scientific publications. Later in his life he gave up many of his material possessions and lived in a small cottage in Wales lacking running water, central heating, and a telephone line.[6] Beer has been described as a "swashbuckling pirate of a man," a "cross between Orson Welles and Socrates," and a guru.[7] His writings addressed subjects as diverse as economic development, socialism, management science, terrorism, and even tantric yoga. Beer was born in 1926 and died in 2002. He was married twice, the first time to Cynthia

Hannaway (1947) and the second time to Sallie Steadman (1968), and fathered seven children.[8]

Among the cybernetics community in the 1950s and 1960s, Beer stands out as someone who built a lucrative private-sector career in the application of cybernetic concepts. By age thirty (1956), Beer was the director of the Department of Operational Research and Cybernetics for all of United Steel, the biggest steel company in Europe.[9] At United Steel, Beer managed more than seventy professionals and supervised pioneering work in computer simulation.[10]

In 1961, when he was thirty-five, Beer left United Steel to codirect the new consulting firm Science in General Management (SIGMA), where he applied cybernetic ideas and operations research (OR) techniques to problems in industry and government (figure 1.1).[11] Jonathan Rosenhead, former president of the Operational Research Society, described SIGMA as "the first substantial operational research consultancy in the UK," and it grew to more than fifty employees under Beer's leadership.[12] Beer doubled his salary while working at SIGMA and lived comfortably. He owned a Rolls Royce and a home in the stockbroker belt of Surrey, England. He named the home Firkins after a unit for measuring beer, and he furnished it with eccentricities, including a goldfish pond in the study, a sound-activated waterfall in the dining room, and walls covered with cork and fur.[13]

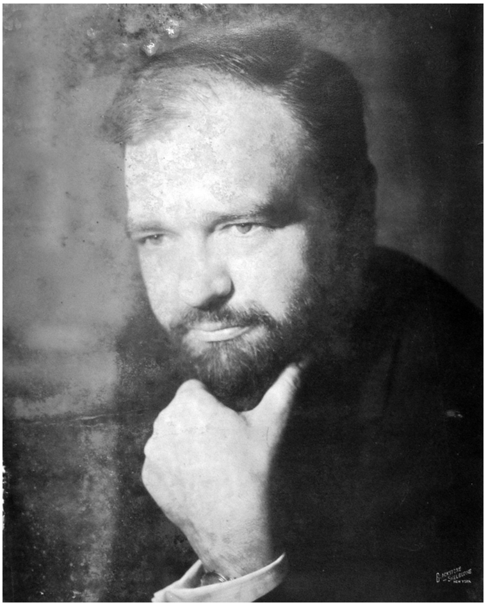

Figure 1.1
Stafford Beer, ca. 1961–1966, when he was employed at SIGMA. Image reproduced with permission from Constantin Malik. Original kept at Liverpool John Moores University, Learning and Information Services, Special Collections and Archives.

Beer left SIGMA after five years and accepted a position as the development director for International Publishing Corporation (IPC), then the largest publishing company in the world. There he applied management science techniques and computer technology to improve company operations and started a research and development unit that advanced printing technology as well as new forms of information and image transfer using computers. His obituary reveals that he coined the term *data highway* during this period, thirty years before high-tech pundits adopted the term *information superhighway* to describe the Internet.[14] In 1970 Beer left IPC to work as an independent consultant, and this was what he was doing when Flores contacted him.

Beer was a prolific writer, publishing ten books on cybernetics in his lifetime. In the ten years between 1961 and 1971, Beer published two books; eight book chapters; twenty-one papers, one of which appeared in the premier science journal *Nature*; and twenty-five articles for popular, business, and scientific publications.[15] Although Beer identified himself as a cybernetician, he was arguably better known for his contributions to operations research, and served as the president of the British Operational Research Society (1970–1971). His book *Decision and Control* won the 1966 Frederick W. Lanchester Prize of the Operations Research Society of America for the best English-language publication of the year in operations research and management science.

Despite his primary ties to industry rather than academia, Beer was well connected with the cybernetic elite in Europe and in the United States.[16] "My stroke of luck was that I came into this field [cybernetics] just as it was getting under way," Beer told me. His charismatic and extroverted personality most likely helped him build his professional network as well. Beer rubbed elbows with some of the leading scientific thinkers of his day, such as Warren McCulloch, Heinz von Foerster, Ross Ashby, and Claude Shannon. Beer met Norbert Wiener, the famous MIT mathematician credited for coining the term *cybernetics*, in 1960 during Beer's first trip to the United States, shortly after the publication of his first book, *Cybernetics and Management* (1959).[17] "Everyone called [Wiener] the father of cybernetics, and he very sweetly called me the father of management cybernetics," Beer said.[18] This title stayed with Beer for the rest of his life.

Beer's accomplishments are even more striking considering that he never received an undergraduate degree. At sixteen he began his studies at the University College London, where he took classes in philosophy, mathematics, psychology, neurophysiology, and statistics. His studies were cut short by mandatory military service in the British armed forces.[19] Later he received a master's degree from the University of Manchester Business School, which the university awarded so Beer would have the qualifications to teach on its faculty. In 2000, when Beer was seventy-three years old, the University of Sunderland recognized the cybernetician's published work by awarding him a doctor of science degree.

While Beer enjoyed many professional successes, he also attracted controversy. His willingness to tackle big problems and propose uncommon solutions drew devoted followers as well as vocal critics, and both sides expressed their opinions of him quite passionately. Beer's charisma and bold claims made him an admired, larger-than-life figure to some and, as he acknowledged, caused others to regard him as a charlatan.[20] One prominent member of the British operations research community opined that Beer's propensity for making grand claims and modeling complex systems in their entirety proved more off-putting than persuasive to some, as did his preference for prose over mathematics. Throughout Beer's life the same characteristics that were regarded as his greatest strengths also fueled his critics. One journalist described him as "a frighteningly articulate man."[21]

Beer's interests spanned poetry, Eastern philosophy, neuroscience, and management, but he always identified himself first as a cybernetician. When he read Wiener's book *Cybernetics* a few years after its publication in 1948, he said it "blew my mind." He realized, "This is what I'm trying to do."[22] Cybernetics, which Wiener defined as the study of "control and communication in the animal and the machine," brought together ideas from across the disciplines—mathematics, engineering, and neurophysiology, among others—and applied them toward understanding the behavior of mechanical, biological, and social systems.[23] The interdisciplinary scope of the new field appealed to Beer, and he saw how such concepts could be applied to industrial management. He created a new definition of cybernetics that better fit his work in management: for Beer, cybernetics became the "science of effective organization." While Beer drew from Wiener and other major figures in cybernetic history, his focus on management and his willingness to apply cybernetic concepts to government organizations and political change processes set him apart from other prominent members of the field.

Cybernetics

Wiener did not originate the term *cybernetics*, but he was the one who made it famous.[24] In 1947 Wiener used the term to describe a collective body of research that combined such formerly disparate topics as the mathematical theory of messages, the study of computation and automata, and the functioning of the neurosystem. Cybernetics brought these fields together to help postulate the shared characteristics of machines and organisms in the areas of communication, feedback, and control so that these behaviors could be better understood. The word *cybernetics* derived from the Greek word *kubernêtês,* or steersman, a choice that recognized the steering engines of ships as "one of the earliest and best developed forms of feedback mechanisms."[25] In ancient Greece the *kubernêtês* was a human being who directed the 170 oarsmen powering a trireme warship and told the rowers to change their activities based on the current speed and course of the craft.

Another translation of *kubernêtês* is "governor." Steam engines such as those created by James Watt in the eighteenth century used centrifugal governors to measure the speed of the engine and regulate the amount of steam that entered the engine chamber. Wiener's reference to these early regulators highlights the feedback and control aspects of cybernetics that fascinated the originators of the field. Although Wiener dates the beginning of cybernetics to around 1942, subsequent historical scholarship has linked the field to earlier work in servomechanisms, radar, telephony, and control engineering.[26]

Cybernetics has many origin stories, but all link the field to research by Wiener and MIT engineer Julian Bigelow that the U.S. government funded during World War II. The challenge was to create an antiaircraft servomechanism capable of accurately aiming weapons to shoot down an enemy aircraft. Bigelow and Wiener viewed the antiaircraft challenge as a problem of feedback, or circular causality, that included the machine as well as the human operator and his decision-making processes.[27] Their inclusion of the human operator led the pair to consult with the Mexican neurophysiologist Arturo Rosenblueth, whom Wiener had gotten to know while Rosenblueth was on the faculty of Harvard Medical School in the early 1930s. With Rosenblueth's help the group began to see the similarity between the physiological forms of feedback found in the human brain and those that were needed in the antiaircraft servomechanism. For example, the mock gun turret Wiener and Bigelow built to test their predictive fire-control apparatus would sometimes swing wildly from one side to another. Rosenblueth associated this behavior with a "purpose tremor," a neurological disorder that caused people to swing their arms from side to side when they tried to pick up an object. Although the latter stemmed from a problem in the cerebellum, the area of the brain in charge of sensory perception and motor control, and the former from a problem in circuit design, Rosenblueth, Wiener, and Bigelow came to see both as problems of feedback, or control through error correction. The study of feedback processes in machines, organisms, and social organizations became a distinguishing feature of cybernetic work and departed from the linear cause-and-effect relationships that, until then, had dominated scientific practice.

In 1948, Wiener published these and other insights in the book *Cybernetics*, which popularized the new science. It "took the postwar engineering world by storm," according to Wiener biographers Flo Conway and Jim Siegelman.[28] The insights about feedback processes in machines and organisms that were advanced by Wiener and others in the "cybernetics group" appealed to researchers in a range of disciplines, including engineering, mathematics, psychology, physiology, and the social sciences. Cybernetic practitioners tried to create a universal science by devising a universal language. This new language allowed cybernetics to make disciplinary "border crossings" and thus increase its legitimacy as a useful way of viewing the world.[29] However, the interpretative flexibility and broad applicability of cybernetic ideas also caused some in the scientific community to dismiss the field as a pseudoscience that lacked disciplinary rigor.[30]

Wiener's book had substantial influence on both sides of the Atlantic. *Cybernetics* inspired engineers to introduce feedback into industrial regulation processes. Conway and Siegelman assert that "the postwar explosion of industrial expansion, economic growth, and technological progress owed much to Wiener's work" and that cybernetics shaped research in such areas as electronics and fueled both the production and consumption of electronic goods.[31] *Cybernetics* was also one of the rare technical books to become a crossover hit with the general public; it went through five printings in the six months after its release. Wiener and his work were featured in the popular magazines *Time*, *Newsweek*, *Life*, the *New Yorker*, and *Fortune*. The connections the book drew between machines and living organisms captured the public's interest, making both cybernetics and Norbert Wiener household words.[32] In its review of *Cybernetics*, *Time* posited that computers might eventually learn "like monstrous and precocious children racing through grammar school" and that "wholly automatic factories are just around the corner."[33] Such statements fueled the public imagination about the future of technology and the social ramifications of the new electronic computer, which, like cybernetics, had also grown out of wartime research. The term took on a futuristic appeal.

Within the academic community, cybernetics promoted a model of scientific research that differed from the departmental structure found on most university campuses in the 1940s. From its earliest days cybernetics valued the cross-disciplinary pollination that occurred when experts from a variety of fields convened to discuss a common problem. The conferences organized by the Josiah Macy Foundation from 1946 to 1953, which laid the groundwork for the field of cybernetics, are the most notable example of such collaboration. For example, the attendance list at the first Macy conference included the anthropologist Gregory Bateson, neurophysiologist Warren McCulloch, mathematician John von Neumann, anthropologist Margaret Mead, logician Walter Pitts, Rosenblueth, Bigelow, and Wiener, among others.[34] Attendees at the Macy conferences drew inspiration from cybernetics' encouragement of the use of common metaphors to describe biological and mechanical systems and took this innovation back to their home disciplines.

In 1956 W. Ross Ashby, a British psychiatrist and Macy conference attendee, wrote that one of the greatest contributions of cybernetics was that it provided a vocabulary and a set of concepts that scientists could use to describe biological, mechanical, and social systems. Cybernetics "is likely to reveal a great number of interesting and suggestive parallelisms between machine and brain and society," Ashby predicted. "And it can provide the common language by which discoveries in one branch can readily be made use of in the others."[35] To Ashby and others, including Beer, cybernetics held promise as a universal language for science and a field with the power to illuminate new commonalities in the behavior of animate and inanimate systems.

Cybernetic approaches quickly spread outside academia and influenced U.S. government efforts to quantify the social in the 1950s and 1960s, albeit in different ways from those pursued by the Chilean government in the early 1970s. Institutions such as MIT and the defense think tank RAND applied techniques from cybernetics and operations research to managing complex social and organizational problems. At RAND these techniques were merged with fields such as game theory, probability, statistics, and econometrics to arrive at a more general theory of "systems analysis."[36] RAND systems analysts sought to quantify the world by remaking complex social and political phenomena into a series of equations whose variables could be fed to an electronic computer. Such equations formed the backbone of mathematical models that, once transformed into software code, could process these variables and be used to predict future system behavior under conditions of uncertainty.

Such computer-based systems proliferated in the U.S. defense community in the 1950s and 1960s, often with the help of scientists from RAND and MIT, and formed part of U.S. efforts for top-down command and control. The SAGE (Semi-Automatic Ground Environment) air defense system is perhaps the most frequently cited example of such a system in the literature of the history of computing. Designed to locate hostile aircraft flying in U.S. airspace, SAGE used real-time radar data to calculate the future position of an enemy aircraft. Paul Edwards, a historian of computing, credits the SAGE system as the first application of computers "to large-scale problems of real-time *control*" rather than for information and data processing.[37] Systems analysis and computer modeling also played important roles in formulating strategies used by the U.S. government during the Vietnam War. These approaches allowed the government to compile detailed quantitative maps of the political climate in different regions of Vietnam and use these data to guide U.S. wartime tactics. Secretary of Defense Robert S. McNamara championed these so-called scientific approaches and used them to create what he believed to be objective policies that emphasized cost effectiveness and centralized decision making.[38]

The U.S. civilian sector also adopted techniques from systems analysis. Fields such as geography, political science, and urban planning adopted quantitative modeling practices that drew from systems analysis, cybernetics, and operations research.[39] These quantitative approaches seemed to give policy makers a way to predict the behavior of complex systems, reduce uncertainty in policy making, improve centralized planning, and ground policy decisions in numerical data. In her study of defense intellectuals in urban planning, historian Jennifer Light notes that the Pittsburgh Department of City Planning pioneered the use of computer modeling, systems analysis, and cybernetics for urban renewal projects in the early 1960s. Pittsburgh city planners drew explicitly from the work of defense intellectuals at RAND and elsewhere and used these approaches to predict future city processes, such as determining residential patterns. In New York City, Mayor John V. Lindsay (1966–1973) used systems analysis to transform city management practices and, with RAND, created the New York City RAND Institute in 1969. Lindsay's view of the city as an information system spurred the creation of computerized data systems to increase data sharing among city departments and centralize decision making and control, although such efforts did not succeed in cutting city operating expenses nor, as Light observes, did they make life noticeably better for city residents.[40] Beer's computerized system for economic management in Chile was later compared with these contemporaneous efforts taking place in New York City.[41]

Increased levels of military funding on university campuses, and the elevated position of science and engineering after World War II, encouraged academic social scientists to adopt these quantitative approaches and raised their profile in the U.S. academy. These approaches have subsequently been criticized for oversimplifying the dynamics of social systems and for encouraging policy makers, academics, and Wall Street bankers to place too much trust in numbers. In addition, critics have pointed out that quantitative approaches encourage top-down management hierarchies that have grafted the structure and culture of the military onto the civilian agencies, businesses, and institutions of a democracy.[42]

Cybernetic ideas helped shape these quantitative systems-oriented approaches to modeling social systems. In the U.S. context, cybernetics has a clear historical link to military engineering activities and what historian Paul Edwards calls the "closed-world" discourse of command and control.[43] But that is not the entire story of cybernetics in the United States or elsewhere. In her study of metaphor in twentieth-century biology, Evelyn Fox Keller asserts that viewing "cybersciences" such as cybernetics, information theory, systems analysis, operations research, and computer science as only "extending the regime of wartime power, of command-control-communication, to the civilian domain" is oversimplistic and one-dimensional. Keller instead argues that the cybersciences also emerged as a way to embrace complexity and "in response to the increasing impracticality of conventional power regimes."[44] This is especially true in the history of British cybernetics and is highly evident in Stafford Beer's work on management cybernetics.

Management Cybernetics

British cybernetics, as practiced by Beer, differed from the U.S. approach in significant ways. In his book *The Cybernetic Brain*, Andrew Pickering distinguishes British cybernetics (as represented by the careers of Beer, Ashby, Grey Walter, Gregory Bateson, R. D. Laing, and Gordon Pask) from the better-known story of cybernetics in the United States, which is often tied to the career of Norbert Wiener and Wiener's military research at MIT during the Second World War. Pickering notes that British cybernetics was tied primarily to psychiatry, not military engineering, and focused on the brain.[45]

According to Pickering, British cyberneticians such as Beer did not view the brain as an organ that created representations of the world or knowledge. Instead, they saw it as an "embodied organ, intrinsically tied into bodily performances."[46] This "cybernetic brain" allowed the body to do things in the world and, above all, to adapt to its environment. As Pickering writes, "The cybernetic brain was not representational but *performative* . . . and its role in performance was *adaptation*."[47] This idea of the performative brain shaped Beer's approach to complex systems and his ideas about management cybernetics.

Indeed Beer's work bears the hallmarks of British cybernetics as described by Pickering. Beer studied and worked in psychiatry, and he made frequent references to the field in his writings. He often used metaphors from neuroscience, including references to the brain and its behavior, to illustrate and support his approach to management. He embraced complexity, emphasized holism, and did not try to describe the complex systems he studied, biological or social, in their entirety. To put it another way, Beer was more interested in studying how systems behaved in the real world than in creating exact representations of how they functioned. Furthermore, he was centrally concerned with developing mechanisms to help these systems self-regulate and survive. He stressed that cybernetics and operations research should drive action, not create mathematical models of increasing complexity and exactitude.[48]

Beer's emphasis on action over mathematical precision set him apart from many of his peers in the academic operations research community who, Beer believed, privileged mathematical abstraction over problem solving.[49] It also set him apart from Wiener, who saw cybernetics as ill-suited for the study of social systems because they could not generate the long-term data sets under the constant conditions that his statistical prediction techniques required.[50]

Beer's management cybernetics cast the company as an organism struggling to survive within a changing external environment. He wrote, "The company is certainly not alive, but it has to behave very much like a living organism. It is essential to the company that it develops techniques for survival in a changing environment: it must adapt itself to its economic, commercial, social and political surroundings and learn from experience."[51] These techniques included building statistical mechanisms that showed managers how the company had reacted to earlier environmental changes so that the manager might better position the business to adapt to future fluctuations and upheavals. Cybernetic management prioritized the long-term survival of the company over the short-term goals of any one department. This attention to overall survival reinforced the importance of holistic management and of Beer's conviction that effective management functioned like the human nervous system. Most companies of his time divided their operations into departments that oversaw the company's activities in assigned areas and dealt with the problems that arose in these areas. Beer believed that this fragmented, reductionist approach could result in decisions that benefited a particular department in the short term but that moved the company toward a greater instability in the long term. Creating the kind of holistic, adaptive system that in Beer's mind functioned like the human nervous system required a different approach to the problem of control.

Adaptive Control

The idea of control is commonly associated with domination. Beer offered a different definition: he defined control as self-regulation, or the ability of a system to adapt to internal and external changes and survive. This alternative approach to control resulted in multiple misunderstandings of Beer's work, and he was repeatedly criticized for using computers to create top-down control systems that his detractors equated with authoritarianism and the loss of individual freedom. Such criticisms extended to the design of Project Cybersyn, but, as this book illustrates, they were to some extent ill-informed. To fully grasp how Beer approached the control problem requires a brief introduction to his cybernetic vocabulary.

Beer was primarily concerned with the study of "exceedingly complex systems," or "systems so involved that they are indescribable in detail."[52] He contrasted exceedingly complex systems with simple but dynamic systems such as a window catch, which has few components and interconnections, and complex systems, which have a greater number of components and connections but can be described in considerable detail (figure 1.2). Beer classified the operation of a computer or the laws of the visible universe as complex systems. Examples of exceedingly complex systems included the economy, the company, or the brain; such systems defied the limits of reductionist

Systems	*Simple*	*Complex*	*Exceedingly complex*
Deterministic	Window catch	Electronic digital computer	Empty
	Billiards	Planetary system	
	Machine-shop lay-out	Automation	
Probabilistic	Penny tossing	Stockholding	The economy
	Jellyfish movements	Conditioned reflexes	The brain
	Statistical quality control	Industrial profitability	The Company

Figure 1.2
Simple, complex, and exceedingly complex systems. Reprinted from Stafford Beer, *Cybernetics and Management*, 2nd ed. (London: English Universities Press, 1967), 18. Image reproduced with permission from Constantin Malik.

mathematical analysis. The behavior of exceedingly complex systems could not be predicted with perfect accuracy, but it could be studied probabilistically. You could have a good idea of what such a system might do, but you could never be one hundred percent certain.

In Beer's opinion, traditional science did a good job of handling simple and complex systems but fell short in its ability to describe, let alone regulate, exceedingly complex systems. Cybernetics, Beer argued, could provide tools for understanding and controlling these exceedingly complex systems and help these systems adapt to problems yet unknown. The trick was to "black-box" parts of the system without losing the key characteristics of the original.[53]

The idea of the black box originated in electrical engineering and referred to a sealed box whose contents are hidden but that can receive an electrical input and whose output the engineer can observe. By varying the input and observing the output, the engineer can discern something about the contents of the box without ever seeing its inner workings. Black-boxing parts of an exceedingly complex system preserved the behavior of the original but did not require the observer to create an exact representation of how the system worked. Beer believed that it is possible to regulate exceedingly complex systems without fully understanding their inner workings, asserting, "It is not necessary to enter the black box to understand the nature of the function it performs" or to grasp the range of the subsystem's behaviors.[54] In other words, it is more important to grasp what things do than to understand fully how they work. To regulate the behavior of such a system requires a regulator that has as much flexibility as the system it wishes to control and that can respond to and regulate all behaviors of subsystems that have been black-boxed.

Creating such a regulator is extremely difficult. Imagine, for example, an exceedingly complex system such as a national economy. It has many component parts, including factories, suppliers of energy and raw materials, and a labor force, all of which are intricately configured and mutually dependent. Each component can assume a range of states or, as Ashby puts it, "a well-defined condition or property that can be recognized if it occurs again."[55] For instance, a factory may constitute one subsystem in the example of the national economy. This factory may have a level of production output that typically falls within a certain range. However, a labor strike could bring production to a halt. Oil prices could increase and cause a significant rise in transportation costs for the factory and negatively affect a range of economic activities throughout the country. In short, the factory can assume a great number of states, only a subset of which is desired. Beer refers to the total number of possible states as the "variety" of a system. In the example given here, each factory can pass through a wide array of states. Once these and other components of the economy are connected, the overarching system (the national economy) can assume an even greater number of states, or have a higher variety.

Controlling an exceedingly complex system with high variety therefore requires a regulator that can react to and govern every one of these potential states, or, to put it another way, respond to the variety of the system. "Often one hears the optimistic demand: 'give me a simple control system; one that cannot go wrong,'" Beer writes. "The trouble with such 'simple' controls is that they have insufficient variety to cope with the variety in the environment. . . . Only variety in the control mechanism can deal successfully with variety in the system controlled."[56] This last observation—that only variety can control variety—is the essence of Ashby's Law of Requisite Variety and a fundamental principle in Beer's cybernetic work.[57]

The Law of Requisite Variety makes intuitive sense: it is impossible to truly control another unless you can respond to all attempts at subversion. This makes it extremely difficult, if not impossible, to control an exceedingly complex system if control is defined as domination. History is filled with instances of human beings' trying to exert control over nature, biology, and other human beings—efforts that have failed because of their limited variety. Many of the most powerful medicines cannot adapt to all permutations of a disease. Recent work in the sociology of science has positioned Beer's idea of control in contrast to the modernist ethos of many science and engineering endeavors, which have sought to govern ecosystems, bodily functions, and natural topographies. Despite the many successes associated with such projects, these efforts at control still have unexpected, and sometimes undesirable, results.[58]

Beer challenged the common definition of control as domination, which he viewed as authoritarian and oppressive and therefore undesirable. It was also "naïve, primitive and ridden with an almost retributive idea of causality." What people viewed as control, Beer continued, was nothing more than "a crude process of coercion," an observation that emphasized the individual agency of the entity being controlled.[59] Instead of using science to dominate the outside world, scientists should focus on identifying the equilibrium conditions among subsystems and developing regulators to help the overall system reach its natural state of stability. Beer emphasized creating lateral communication channels among the different subsystems so that the changes in one subsystem could be absorbed by changes in the others.[60] This approach, he argued, took advantage of the flexibility of each subsystem. Instead of creating a regulator to fix the behavior of each subsystem, he found ways to couple subsystems together so that they could respond to each other and adapt. Such adaptive couplings helped maintain the stability of the overall system.

Beer called the natural state of system stability *homeostasis*.[61] The term refers to the ability of a system to withstand disturbances in its external environment through its own dynamic self-regulation, such as that achieved by coupling subsystems to one another. Beer argued that reaching homeostasis is crucial to the survival of any system, whether it is mechanical, biological, or social. Control through homeostasis rather than through domination gives the system greater flexibility and facilitated adaptation, Beer argued. He therefore proposed an alternative idea of control, which he defined as "a homeostatic machine for regulating itself."[62] In a 1969 speech before the United Nations Educational, Social, and Cultural Organization, Beer stated that the "sensible course for the manager is not to try to change the system's internal behavior . . . *but to change its structure*—so that its natural systemic behavior becomes different. All of this says that management is not so much part of the system managed as it is the system's own designer."[63] In other words, cybernetic management as described by Beer looked for ways to redesign the structure of a company or state enterprise so that it would naturally tend toward stability and the desired behavior.

In addition, cybernetic management sought to create a balance between horizontal and vertical forms of communication and control. Because changes in one subsystem could be absorbed and adapted to by changes in others (via lateral communication), each subsystem retained the ability to change its behavior, within certain limits, without threatening the overall stability of the system and could do so without direction from the vertical chain of command. To look at it another way, cybernetic management approached the control problem in a way that preserved a degree of freedom and autonomy for the parts without sacrificing the stability of the whole.

The first edition of Beer's 1959 book *Cybernetics and Management* did not make many references to computer technology, although the book's description of a cybernetic factory includes several tasks suitable for large-scale data processing, among them the generation of statistical data to predict the future behavior of the company. The second edition of the text, published eight years later in 1967, includes a postscript—"Progress to the Cybernetic Firm"—and a section dedicated to the misuse of computers in industry. (Beer often objected to how businesses and government offices used computers.)

Mainframe computer technology entered the business world during the 1950s and 1960s, primarily as a means of increasing the speed and volume of data processing. Beer argued that most applications simply automated existing procedures and operations within the company instead of taking advantage of the new capabilities offered by computer technology to envision new forms of organization and better methods of management. Applied differently, computer technology could help organize the parts of the business into a better-functioning whole and allow companies to focus on the future instead of compiling pages of data that documented past performance. Computers did not need to reinforce existing management hierarchies and procedures; instead, they could bring about structural transformation within a company and help it form new communications channels, generate and exchange information dynamically, and decrease the time required for those in the company to make an informed decision. In short, Beer believed that computer technology, used differently, could help implement cybernetic approaches to management.[64] His focus was not on creating more advanced machines but rather on using existing computer technologies to develop more advanced systems of organization.

Cybernetics and Chilean Socialism

Beer's ideas on management cybernetics resembled the Chilean approach to democratic socialism. First, Allende and Popular Unity, like Beer, wanted to make structural changes and wanted them to happen quickly. However, they needed to carry out these changes in a way that did not threaten the stability of existing democratic institutions. Second, Allende and his government, Popular Unity, did not want to impose these changes on the Chilean people from above. The government wanted change to occur within a democratic framework and in a way that preserved civil liberties and respected dissenting voices. Chilean democratic socialism, like management cybernetics, thus wanted to find a balance between centralized control and individual freedom. Third, the Chilean government needed to develop ways to manage the growing national economy, and industrial management constituted one of Beer's core areas of expertise. In the next chapter I will explore how Beer's approach to industrial management addressed the goals of Allende's economic program and, in particular, the government's emphasis on raising national production. For now it is sufficient to say that Beer's work in cybernetics was exploring some of the same issues as Chilean socialism, although Beer was working in the domain of science rather than politics. This common conceptual ground motivated Flores to contact Beer. But how this connection occurred is a story of historical contingency, and it requires stepping back in time to the early 1960s.

By 1961 Beer had achieved an international reputation in Europe and the United States. Around 1962, when he was codirector of SIGMA, the director of Chile's steel industry requested SIGMA's services. Beer refused to go himself—he had never been to South America, and his hectic schedule made the lengthy transit time seem unreasonable—but he put together a team of English and Spanish employees to travel to Chile in his place. SIGMA's work in the Chilean steel industry had gradually expanded to include the railways. Because the amount of work was large, the SIGMA team in Chile often hired students to pick up the slack. Among them was the young Fernando Flores, who then was studying industrial engineering at the Catholic University in Santiago.

Flores was born in 1943 in the town of Talca, which is located south of the Chilean capital city of Santiago. His father was a railroad engineer, and his mother owned a small lumber company. He was a good student with a quick mind and ability for mathematics. Although Flores did not know what he wanted to do with his life, he realized that becoming an engineer was "a big deal," and so he applied to the School of Engineering at the prestigious Catholic University and was accepted. In a 2003 interview he speculated that he may have been the first in his family to receive a university education.[65] Flores's discovery of cybernetics and of Beer resulted from a particular series of personal connections, work experiences, and political changes that occurred outside his formal university education. Within the university Flores studied operations research with Arnoldo Hax, the director of the school of engineering at the Catholic University (1963–1964) who later accepted a professorship at MIT's Sloan School of Management.

Because Flores was trained in operations research, SIGMA hired him to work on the contract for Chilean railways. It was then that he discovered *Cybernetics and Management*, a book he describes as "visionary." Flores graduated in 1968 with a degree in industrial engineering. After graduation he visited Hax in the United States, and someone serendipitously passed him a copy of Beer's second book, *Decision and Control*. "I found this book to be better than the others," Flores said, "more concrete, more clear, intriguing. I found that [Beer] had a great mind for these kinds of things. Different from the others, who always thought that operations research was connected with techniques. They didn't have the core, and I was looking for the core. . . . Always." Flores was drawn to the connective, philosophical foundation that cybernetics offered and that Beer articulated. Flores believed that Beer's approach to management was the best around.[66]

From 1968 to 1970 Flores served as the academic director of the engineering school at the Catholic University, although his duties gradually expanded to include activities throughout the university. The university reform movement was under way during this period, and Flores oversaw many changes in the university's engineering curriculum, including efforts to increase community involvement with university activities. Like many of his contemporaries, Flores was active in academic and political circles. In 1969 a group of young intellectuals at the Catholic University, including Flores, broke from the Christian Democratic Party and established the Movement of Popular Unitary Action (MAPU), a small political party of young intellectuals who were critical of the centrist Christian Democrats and Chilean president Eduardo Frei Montalva (1964–1970); they aligned themselves with the Communists and Socialists of the leftist Popular Unity coalition. The addition of the MAPU to Popular Unity, combined with the inability of the right and the Christian Democrats to form a winning coalition, contributed to the Socialist Allende's narrow victory in the 1970 presidential election.

As an acknowledgment of Flores's political loyalty and technical competency, the Allende government appointed Flores the general technical manager of the Corporación de Fomento de la Producción (CORFO), the State Development Corporation, which Allende charged with nationalizing Chilean industry. Flores held the third-highest position within the agency, the highest position held there by a member of the MAPU, and the management position most directly linked to the daily regulation of the nationalized factories.[67]

Flores remembered Beer's writings and thought that the ideas found in his management cybernetics overlapped with the political ideas of the Chilean road to socialism, in that Chilean democratic socialism was struggling with the question of "how to combine the autonomy of individuals with the [needs of the] community." From his perspective in CORFO, Flores felt that the government was "paying pure lip service" to this question and had "nothing concrete" that could be put into practice. Flores believed that Beer might give the government a way to turn its political ideology into practice.[68]

Flores also had the financial and political resources to bring Beer to Chile in order to apply his expertise to the Chilean economy. "When I came to CORFO," Flores said, "I found that I had the small amount of power that I needed to do something bigger." He decided to use part of that power to bring Beer to Chile. Few in Chile, outside academia, knew of cybernetics, and management cybernetics was even more obscure. Flores's decision to approach Beer was well outside mainstream thinking at the development agency. Darío Pavez, then its general manager and Flores's boss, reportedly viewed Flores's decision to recruit Beer as crazy. However, he decided to give Flores leeway because he recognized Flores's value to CORFO.[69] It also helped that Flores was a very persuasive individual despite his youth. He expressed his ideas passionately and was not afraid to ruffle feathers to get things done. He was also large physically; Beer later described the young engineer as a bear. In addition, Flores had a sharp mind and strong personality.

Flores was drawn to Beer's work because of the connection he saw between cybernetics and socialism. Flores's personality and position in the government allowed him to transform these conceptual commonalities into a real collaboration.

Beer's New Models

Flores did not know that Beer's interest in how to use cybernetics for social change had increased in the late 1960s and early 1970s, as had his commitment to improving government effectiveness by developing ways to change its structure. In 1970 alone, Beer delivered ten public lectures that he referred to as "arguments of change."[70] He later published these lectures in his fifth book, *Platform for Change* (1975).

In addition, Beer had been working on two innovative—but potentially related—models of systems organization: the Liberty Machine and the Viable System Model. The Liberty Machine (1970) was a new kind of technological system for government administration. Beer argued that such a system could be built without using cutting-edge technology and that it could help government offices minimize bureaucracy and adapt to crises. Beer spent 1971 finalizing the Viable System Model, a general model that he believed balanced centralized and decentralized forms of control in organizations. He argued that it could be applied to a range of organizations, including government. From Beer's perspective, both the Liberty Machine and the Viable System Model could be applied to address the tension between top-down and bottom-up decision making in Chilean socialism and the challenges Chile faced as a developing nation with limited technological resources. Thus, the invitation from Flores was not only a chance for Beer to apply his cybernetic ideas on a national scale but also a consulting opportunity that aligned perfectly with the cybernetician's intellectual trajectory.

The Liberty Machine

Beer presented his idea for a Liberty Machine in a 1970 keynote address to the Conference on the Environment organized by the American Society for Cybernetics in Washington, D.C. An edited version of this text later appeared in a 1971 edition of the journal *Futures* and later in *Platform for Change*. In the address Beer described government as an "elaborate and ponderous" machine that has such "immense inertia" that changing government organization seems to require "destroying the machinery of the state and going through a phase of anarchy."[71] Ineffective organization had serious long-term implications and limited government efficacy to act in the present and plan for the future.[72] Therefore, Beer argued that government institutions needed to change and that this could be accomplished without the chaos of destroying the existing state.

The Liberty Machine modeled a sociotechnical system that functioned as a disseminated network, not a hierarchy; it treated information, not authority, as the basis for action, and operated in close to real time to facilitate instant decision making and eschew bureaucratic protocols. Beer contended that this design promoted action over bureaucratic practice and prevented top-down tyranny by creating a distributed network of shared information. The Liberty Machine distributed decision making across different government offices, but it also required all subordinate offices to limit their actions so as not to threaten the survival of the overall organization, in this case, a government. The Liberty Machine thus achieved the balance between centralized control and individual freedom that had characterized Beer's earlier work.

Beer posited that such a Liberty Machine could create a government where "competent information is free to act," meaning that once government officials become aware of a problem, they could address it quickly; expert knowledge, not bureaucratic politics, would guide policy. However, Beer did not critically explore what constitutes "competent information" or how cybernetics might resolve disagreements within the scientific community or within other communities of expertise. Moreover, it is not clear how he separated bureaucracy from a system of checks and balances that might slow action but prevent abuse.

Beer envisioned that the physical Liberty Machine would consist of a series of operations rooms that received real-time information from the different systems being monitored and used computers to "distil the information content."[73] The people inside these rooms, whom Beer described as "responsible officials answerable to constitutional masters," would use this information to run simulations and generate hypotheses about future system behavior. Color television screens would be used to display data to these officials.

The image of a futuristic operations room would come to define Project Cybersyn. Beer's interest in building such rooms has an interesting etiology. Beer came of age during World War II, and the successful use of operations research techniques by the

British armed forces during the war left a lasting impression on him. In a 2001 interview, Beer said that through his work at SIGMA he "was trying to change industry and government in the same way the army, navy and air force had been changed by making mathematical models and other kinds of models" during World War II. The image of the war room that Winston Churchill used to direct and control the complexities of the British war effort also deeply impressed Beer. In his 1968 book *Management Science*, Beer argues, "The 'Battle of Britain' in World War II was successful only because it could be directed, from moment to moment, from this central control headquarters near London. This was made possible by information gathering and communication techniques unknown a few years previously."[74] In his 1970 inaugural address as the new president of the British Operational Research Society, Beer eluded to the battle encounters "spread out on a vast map in the war-time Operations Room" as a successful governing technique that had worked for Churchill and the British armed forces and that could be a cornerstone for cybernetic government. "I envision a government operations center," Beer said, "laid out on comparable lines, relating the pieces of the national problem in an integral way. Industrial managements could have this room if they wanted it; so could a new kind of Cabinet Office."[75] By 1971 Beer had concluded that governments did not necessarily need access to the most cutting-edge technologies to construct such a system. A "tool of this potency could be forged by anyone commanding adequate resources," who could then "take virtual control of affairs," Beer wrote.[76] The Liberty Machine, a distributed decision-making apparatus of operations rooms connected by real-time information-sharing channels, was a proposal waiting for a government to take a chance on its implementation.

The Viable System Model

The Viable System Model is one of the most central and enduring concepts in all of Beer's work. It was the subject of three of his ten books on cybernetics, and Beer wrote in 1984 that he had been on a quest to explain "how systems are viable" since the 1950s.[77] Beer first presented the Viable System Model in his fourth book, *Brain of the Firm* (1972), but the model was almost fully formed by the time Flores contacted him in July 1971. In *Brain of the Firm*, Beer defines a viable system as "a system that survives. It coheres; it is integral. It is homeostatically balanced both internally and externally, but has none the less [*sic*] mechanisms and opportunities to grow and to learn, to evolve and to adapt—to become more and more potent in its environment."[78] By the mid-1980s Beer had refined this definition even further to create a system that is "capable of independent existence."[79] Here I describe the Viable System Model as Beer described it in *Brain of the Firm*, supplemented with commentary from some of his later works, to enable the reader to understand the system as it was presented to the Chilean team. However, since the model evolved in Beer's subsequent work, the description presented here is not identical to the one used today.[80]

The Viable System Model offered a management structure for the regulation of exceedingly complex systems. It was based on Beer's understanding of how the human nervous system functioned, and it applied these insights more generally to the behavior of organizations such as a company, government, or factory.[81] Though Beer would later describe Allende's Chile as the "most significant and large-scale" application of the Viable System Model, it was also a testing ground for the model, which in size and scope Beer was never able to equal.[82]

In its full form the Viable System Model is complex; what follows is only a brief description of some of its general principles. Despite the model's biological origins, Beer maintained that the abstraction of the structure could be applied in numerous contexts, including the firm, the body, and the state. In keeping with Beer's emphasis on performance rather than representation, it was not a model that accurately represented what these systems were; rather, it was a model that described how these systems behaved. The Viable System Model functioned recursively: the parts of a viable system were also viable, and their behavior could be described using the Viable System Model. Beer explains: "The whole is always encapsulated in each part. . . . This is a lesson learned from biology where we find the genetic blue-print of the whole organism in every cell."[83] Thus, Beer maintained that the state, the company, the worker, and the cell all exhibit the same series of structural relationships.

The Viable System Model devised ways to promote vertical *and* lateral communication. It offered a balance between centralized and decentralized control that prevented both the tyranny of authoritarianism and the chaos of total freedom. Beer considered viable systems to be largely self-organizing. Therefore, the model sought to maximize the autonomy of its component parts so that they could organize themselves as they saw fit. At the same time, it retained channels for vertical control to maintain the stability of the whole system. These aspects of the Viable System Model shaped the design of Project Cybersyn and provide another illustration of how Beer and Popular Unity were exploring similar approaches to the problem of control.

The Viable System Model consisted of five tiers that Beer based on the human nervous system.[84] As in Beer's other work, the model black-boxed much of the system's complexity into subsystems. The model also established channels of communication that coupled these subsystems to one another. This allowed them to share information, adapt to one another and the outside world, and keep the entire system stable.

Figure 1.3 provides a biological rendering of Beer's five-tier system, but in its most basic form the Viable System Model resembles a flow chart. In his writings Beer switches freely among metaphors drawn from organizations, organisms, and machines when describing each of the system's five levels. These different metaphors helped him to communicate his ideas to his reader, emphasize the ideas' scientific origin, and stress that biological, social, and mechanical systems shared similar characteristics. Beer first

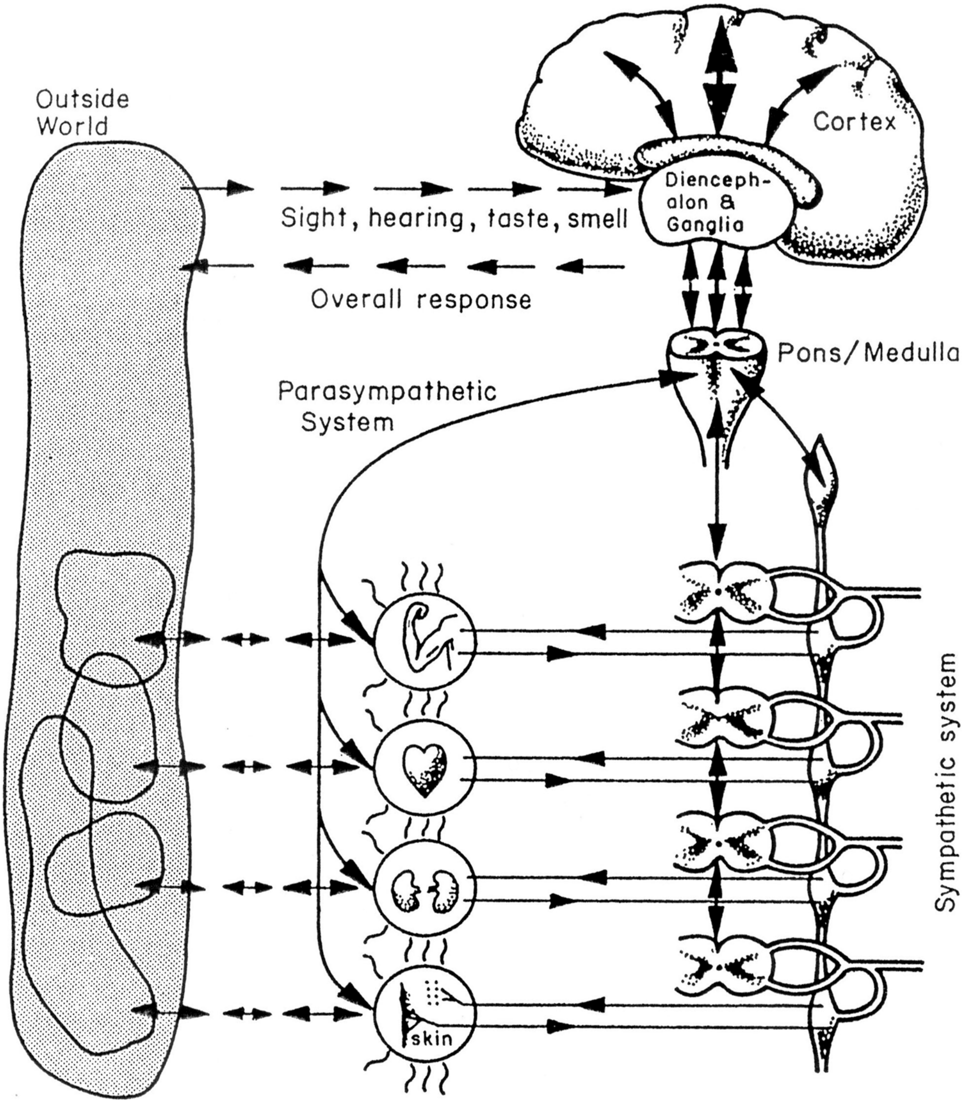

Figure 1.3

Viable System Model (biological). Reprinted from Stafford Beer, *Brain of the Firm: The Managerial Cybernetics of Organization*, 2nd ed. (New York: J. Wiley, 1981), 131. Image reproduced with permission from Constantin Malik.

described the model in its biological form, which I present here. I will later explore how Beer mapped the model onto Chilean industrial production.

Beer referred to System One of the Viable System Model as the sensory level. It consisted of the limbs and bodily organs (such as the lungs, heart, or kidneys). Because members of System One are in contact with their environment, they are able to respond to local conditions and behave in an "essentially autonomous" manner, although they are regulated to behave in ways that ensure the stability of the entire body. For example, our kidneys and heart, when working properly, automatically adjust to the surrounding conditions. Under normal conditions our breathing also happens automatically without conscious thought. Beer asserted that in most instances, our body parts are capable of regulating their own behavior. However, changes in the behavior of one organ may affect the operating environment, and thus the behavior, of other body parts.

System Two acts as a cybernetic spinal cord. It enables rapid lateral communication among the different body parts and organs so that they can coordinate their actions and adapt to one another's behavior. "Each organ of the body," writes Beer, "would be isolated on its lateral axis if it were not for the arrangement of each organ's own controller into a cohesive set of such controllers—which we have called System Two."[85] System Two also filters information from System One and passes the most important information upward to System Three. Given its name, System Two seems to be hierarchically above System One, but Beer insisted that it was not; instead, he countered, System Two should be seen as a service to System One. The Viable System Model did not impose a hierarchical form of management in a traditional sense. The dynamic communication between System One and System Two enabled a form of adaptive management that was made possible by rapid information exchange, coordinated action, and shared understanding.[86]

System Three (which Beer equated to the pons, medulla, and cerebellum of the brain) monitors the behavior of each organ (System One), as well as the organs' collective interaction, and works to keep the body functioning properly under normal conditions. In management terms, Beer later described System Three as being "responsible for the *internal* and *immediate* functions of the enterprise: its 'here-and-now,' day-to-day management."[87] Because System Three has access to the macroscopic picture of what is going on at the lower levels, it can help coordinate System One actions to maintain the overall stability of the body or the enterprise. Beer described System Three as belonging to "the vertical command axis"; it is a "transmitter of policy and special instructions," and "a receiver of information about the internal environment."[88] However, System Three does not receive data on all aspects of System One's operation, only the information deemed most important. This filtering allows System Three to grasp the totality of what is taking place without being overwhelmed by minutiae. Periodic audits of System One behavior allow System Three to make sure it is not losing important details