INTRODUCTION

The Quest for Innovation and Cultures of Technology

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It is impossible to imagine the future without referring to the concept of innovation. Like an almost invisible tether suspended from a spaceship, the quest for innovation involves taking measurements in an unknown environment. Its bearings are confined to the tiny base in which it has been set up, while the surrounding space is vast, cold, and indifferent. And yet, this quest continues its exploration, fueled by human ingenuity and driven by insatiable curiosity. Built as a result of today's scientific and technological knowledge and the range of skills available at present it extends forward in time is guided by what human imagination and determination have to offer: vague promises of improvement, the desire to understand, and hence the will to control. Never before in our history has there been such a view of the future that offers unbounded opportunities. While science and technology make innovations possible at an unprecedented rate, the social order and especially the economic organization of today's societies have created a culture of competition and economic growth that continues to extend the horizon toward the unknown future. With the onset of modernity, contingencies were embraced. Now we are being asked to embrace the inherent uncertainty residing in the endless process of innovation.

In this chapter I will first analyze the quest for innovation and explore some of the reasons why it has achieved such prominence and (seeming) urgency. I will argue that innovation seeks to negotiate a future that has become more fragile and even more inherently uncertain. I will then compare the use of this concept with an historical precedent, the rise of the concept of technology in the nineteenth century, and identify which societal void is filled by the concept of innovation. I will then return to what I call "cultures of tech-

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nology," as one of the most salient features of this quest for innovation. Cultures of technology takes seriously the proposition that culture matters. But to approach technology under a cultural perspective opens new avenues for exploring how technology works, including the meanings we attach to newly emerging technologies and innovations. The aim is to explore nothing more and nothing less than the complex interrelationships between culture, society, and technology.

The Future of the Past

While today the future appears to be highly uncertain and fragile, exacerbated by the relentlessly ongoing process of globalization and, more recently, of the fear of the further spread of global terrorism, the view of the future was very different only thirty years ago. Looking backward may therefore throw light on what has changed. Perhaps no other book is such a compelling witness as *The Limits to Growth,*[1] published under the auspices of the Club of Rome. This ambitious research project triggered an unprecedented worldwide response since it was the first computer-based world model with normative assumptions, which had emerged from the young field of dynamic systems modeling. Some interpreted it as a courageous attempt to confront in a holistic way all of the pressing problems of the world, while others, especially other academics, were more skeptical in their assessments. But even they had to concede that the public response to the study was impressive. One review headline read, "The computer that printed out W★O★L★F." The "wolf" that had allegedly been sighted, however, was more than a mere figment of the imagination on the part of a world in crisis. The book represented a thinly disguised attack on one of the era's hitherto unquestioned ideological dogmas. It contained the sharpest possible warning of the environmental and demographic consequences of a commitment to the project of continued, undifferentiated, and unimpeded economic growth. According to the authors and to their sponsor, this was the real cause underlying the most urgent problems facing humanity. The various crisis scenarios that the model produced demanded action, as well as a reversal of the dominant thinking, if humanity and its relentless exploitation of the environment were to be pulled back from the abyss at the last possible moment.

It is quite intriguing to look back at the projections of a future that by now has become the past.[2] It may seem paradoxical to claim that one of the more lasting legacies of *The Limits to Growth* has been an altered sense of the future and of the ways of coping with its inherent fragility. While the world models of J. W. Forrester and D. L. Meadows were being devised, the future was considered predictable to a degree. The belief in its predictability underpinned the strong media response elicited by the computer-generated consequences. Based upon this belief it was possible to link the results that had been obtained through

mathematical probabilities to the starkly normative claims that accompanied them, namely, that it was mandatory to change individual and collective behavior, and the economy and politics in a way that would prevent the collapse otherwise predicted.

Today's sense of the future could not be more different. It is spoken about in the conditional, and should be used exclusively as a plural despite the linguistic oddity. Uncertainties and contingencies abound. Various kinds of risks, of different proportions and subject to varying perceptions, have become an integral part of our lives—replacing the fear of the one big catastrophe that loomed large in the 1970s: the collapse of the environment. Even the latest spread of fears—fear of an enemy who is believed to be capable of the most wanton acts of destruction—fits into this overall picture, despite the difference in scale and content. The future has therefore moved closer to the present. Concomitantly, the tools to imagine the future in a more systematic way have also evolved. Models are recognized as being provisional; they capture a fluctuating present in a conjectural mode that projects certain assumptions and their dynamics. The process of thinking through, and reflecting upon, one's built-in assumptions has become far more important than the actual findings. Results of the process of modeling are clearly seen to possess a highly preliminary and precarious status. In using the various tools of forecasting or of backcasting, of future scanning or devising road maps, of creating visions or of celebrating the creative forces of chaos, flexibility and creativity have become the hallmarks of this process. In its exuberant rhetoric the process mirrors the predominant mechanism, which is widely believed to incarnate the promise of optimal adaptation to the uncertainties of the future: the market.

In retrospect, the three golden decades of the last part of the twentieth century seem to be far more removed than mere chronology would indicate, firmly rooted as they were in the centralized structures of the welfare state. Even the slightest achievements of this bygone age, in which the state was dominant in setting the political, social, and to some degree also the economic agenda, were translated into an astonishingly rich but equally rigid arrangement of policies and regulations. This was stimulated by the belief, at least in some countries in Europe, that planning was not only possible, but also a sign of good government. Looking back from today's vantage point, where governing has yielded to governance and statecraft has been all but taken over by stagecraft,[3] it comes as a shock to perceive what is missing in the way we perceive the future. It is not so much the technocratic streak that colored both the world models and other predictions of the future as it was the lack of other perspectives. What is markedly absent when looking back today is the multitude of consumers and voters who constitute democratic plurality. These individuals (and it is a highly individualized view which prevails today) are aware of their right to choose. They are expected to participate (and they insist upon participating) in accordance with the rules of the game. Their existence is per-

vasively felt in the political and economic imagination. Today we would ask: how can one conceive of the future without taking into account the views of the future held by all of these actors who are supposed to shape it?

The links between the present and the unknown future have always been a source of fascination, and each culture, each historical epoch, has structured them in diverse ways. The urge to divine what was to come lay at the roots of the ancient Chinese arts of numbers and mathematics. Christian theology pictured a future based upon the belief in salvation. And, for probably most of our history, fate reigned supreme in many societies. With modernity came the belief that the future could be planned, at least to a certain degree. The advances made in such fields of knowledge as mathematical probability theory enabled new social institutions to gain an economically viable footing, and to be able to cope with the unknowns of the future. The promises of modernity were also premised upon a new confidence in the achievements of an increasingly self-governing society. Today, our public belief is that innovation enables us to negotiate the future, after having had to accept that there are limits to planning. Innovation embraces the uncertainties inherent in the future—and attempts to seize whatever opportunities they have to offer. The meaning of the concept of innovation has been changed. While the configuration of known elements is still at its core, it also transcends what is known in a radical, evolutionary sense.

Why has the quest for innovation become so omnipresent at the beginning of the twenty-first century? When and how did the collective obsession with innovation arise—not only in the rhetoric of politics, which always carries promises of a better future, but also among industrialists who seek to adapt to the new economy of increasing returns[4] and to play the high-tech game. Even the quest for discoveries, whose significance as an indispensable epistemic base is sometimes realized only much later, is now moving closer to possible technological applications. Most scientists are aware of the fact that they are also expected to seek possible ways of "translating" their basic findings and discoveries that will be useful to society in one way or another. While curiosity has not disappeared, it too now takes part in the dominant motivation for engaging in research.

The current emphasis on innovation does not mean that this is a new phenomenon, nor that innovation was not seen as highly desirable and crucial for economic growth before. But—to mention one example—innovative processes are understood as endogenous phenomena in orthodox neoclassical economic theory. To this day, J. A. Schumpeter's proposals for an economic theory of innovation remain outside mainstream economic thought. Economists who took them as a starting point for modeling techniques, or who wanted to consider processes of innovation empirically, depart critically from neoclassical theory. Empirically speaking, processes of innovation are the result of specific activities aimed at changing the production process or at introducing new

products; their results cannot be forecasted in detail. The whole problematic lies in the unpredictability of the success of attempts at innovation. Investments in innovation cannot be derived rationally due to the strategic uncertainty with respect to the action of other actors and to the uncertainty of the utility of the innovation. As Schumpeter argued a long time ago in *The Theory of Economic Development,* entrepreneurs are indeed interested in profit, but innovation cannot be understood as motivated by goal oriented utility maximizing alone.[5]

One theme I want to propose here is that the quest for innovation fills a conceptual void in our collective imagining of the future. This is an important void, insofar as it holds the key to a future that otherwise escapes us. Our thinking about the future is itself historically constrained. It has moved precariously between some degree of stability and a principled openness to the unforeseen. It has become subject to an evolutionary perspective, which brings with it a notion of radical openness. Our projections of the future have begun to oscillate between the emerging order on the one hand, and the edge of chaos on the other hand. Against the background of our growing knowledge about the dynamics of complex systems, thinking about the future has become less mechanistic and naive. It has perhaps even become reflexive in the sense that thinking about the future is no longer primarily based upon "what is likely to happen." Questions have shifted toward knowledge of the actors imagining different kinds of futures. In one domain in particular, financial markets, this kind of reasoning, and the mathematical tools that accompany it, have reached an impressive level of sophistication.[6]

Imaginary constructs of the future serve different social functions in public and private discourse alike. But they have also become part of the various agendas for innovation, with the intent to mobilize cultural, economic, and social resources that will serve as indispensable preconditions for technological innovation in particular. Public discourse about innovation, the rhetoric it uses, and the target groups it addresses, has become almost as important as its substantive, material content. Discourse about "technological pulls" or "technological pushes," which presupposes that new technological development will be followed by appropriate levels of demands or social acceptance, has lost credibility in a civil society whose acknowledged complexity and plurality includes the views of its various stakeholder groups, whose preferences are not predetermined. While the extension of views of the future necessarily leads to increased uncertainty, it also promises to widen the breadth of opportunities that come with it.

The conceptual void arises for many different reasons. One of the reasons, however, emerges from the changing nature of the relationship between the state and the market. Because innovation is both a socioeconomic and a technological process, the support for innovation and entrepreneurship is increasingly seen as being also a pro-active responsibility of governments. In their classic book, *How the West Grew Rich,* Nathan Rosenberg and L. E. Birdzell Jr.

wrote in 1985: "In all well-ordered societies, political authority is dedicated to stability, security, and the status quo. It is thus singularly ill-qualified to direct or channel activity intended to produce instability, insecurity, and change."[7] Today, all highly industrialized nation-states have developed a set of policy tools to foster technological innovation and investment in research. While technological innovation in a more narrow or technical sense still occurs and can therefore be defined as "the successful implementation (in commerce or management) of a technical new idea to the institution creating it,"[8] or as "the process by which firms master and get into practice product designs and manufacturing processes that are new to them,…"[9] it is now recognized that what is required is an innovative society.

Political agendas aimed at promoting technological innovation, including "foresight" exercises of various kinds, thus serve as proxies for constructing a shared vision of the future. This process is in turn indicative of the necessity to cope in both an active and an interactive fashion with the fragmentary and undecided nature of what we regard to be the future. There is a growing realization that innovation processes do not automatically follow from the results of research, whatever their potential may be. The "linear model," which foresees that basic research will somehow find its way to being transferred or translated into applied research, which will in turn later appear on the market in the form of commercially viable products or processes, appears as an idealized version of what happened in a given historical period, namely, after World War II.[10] Nor can today's innovation processes be left to entrepreneurs alone, however strong their "restlessness" (in a Schumpeterian sense) may be. The omnipresent quest for innovation, caught up as it has been in a globalized world, is a hybrid of many elements. It includes the availability of venture capital, and the creativity of determined individuals as much as the flexibility of institutions and regulatory processes. An ever-expanding knowledge base and the appropriate research system must be in tune as well with the wider expectations of society, whose ultimate acceptance will be decisive. Innovation stands for social change, which is embraced by some and feared by others. And, as with modernity's previous march forward, there will be winners and losers. Innovation also faces barriers that are much more difficult to detect, because they inhere in the nature of institutions and of large sociotechnical systems. Nor does innovation necessarily always offer the best technological solutions. Technology can become locked-in, as can innovations. All this is part of a public discourse intent on moving forward toward an uncertain future.

A Historical Precedent

It is tempting to compare the recent emergence of innovation as a major concept of our times to an historical precedent. In a curious twist, concepts that

are taken for granted are often projected backward into the past as though they had always existed. Leo Marx has shown that this occurred in the nineteenth century with the then-novel concept of technology.[11] The belated emergence of the word technology, used to name what allegedly was driving history during the mid nineteenth century in the United States, is a reminder of how an old word can be invested with new meaning, and thus often serves as a marker for far-reaching developments and for ongoing changes in a society and in its culture.

During the 1840s in the United States two kinds of large-scale changes had become apparent: one ideological, involving the prevailing ideas about the mechanical arts; the other substantive, affecting the organizational and material matrix of the mechanical arts. The first is exemplified by a speech given by Senator Daniel Webster at the opening of a new section of the railroad in New Hampshire. He celebrates his "extraordinary era," "the progress of the age [that] has almost outstripped human belief," and the "future [that] is known only to Omniscience."[12] The perceived relationship between innovations in science and the mechanical arts and the prevailing belief in progress is thereby subtly altered. Of course, the idea of progress had been bound up with the accelerating rate of scientific discoveries and technical inventions before. But, as Marx explains, advances in science and in the mechanical arts had been important for the thinkers of the Enlightenment as a means to arriving at social and political ends, and not as ends in themselves. This distinction had changed by Webster's time, certainly in the United States. Webster's audience no longer thought of the railroad as merely a means to achieving social and political progress. For the new entrepreneurial elite, the mechanical arts were highly visible, and this change was ripe for the emergence of a new word: technology. The blurring of the distinction between mechanical means and political or normative ends, however, did meet with strong criticism.

The second substantive change occurred in the material and organizational character of the mechanical arts. The change was embodied in machines, but in the second half of the nineteenth century the machine was replaced by a new kind of sociotechnological system. The railroad was among the earliest and most visible, large-scale technological systems of its time. A novel feature of such a system is that the crucial mechanical component, the physical artifact itself, constitutes only a small part of the whole. Concomitantly, the organizational features that were required to render it operational have expanded tremendously, from ancillary equipment and large corporate business organizations with unprecedented capital investment, all the way to the new sets of skills required from the workforce. While the merger of science and the practical arts and industry was already under way, it was not until the end of the century with the growth of the electrical and chemical industries that the transformative power of the new entity—now called technology—became fully visible. And, as so often before, a pioneer had already been using the word far ahead of his time.

It was a Boston botanist and physician, Jacob Bigelow, who as early as 1826, "adopted the general name of Technology, a word sufficiently expressive" to denote "the practical applications of science, which may be considered useful, by promoting the benefit of society, together with the emolument of those who pursue them." The greatest success in dissemination came when the term technology was used in naming a new institution of higher learning, the Massachusetts Institute of Technology, now better known as MIT, in 1862.[13]

Before leaving this historical reconstruction of the arrival of a new word, and its successful closing of a semantic gap, it is worth recalling what had been missing: a concept that would capture a new form of power and of progress, one that far exceeded in degree, scope, and scale the relatively limited capacity of the merely useful, mechanical, practical, or industrial arts as a driver of social change. What was needed was a concept that would not merely signify a means to achieving progress, but that would signify the progress that had been achieved and—for all to see—continued to do so.

Innovation Fills the Void

The quest for innovation fills another conceptual void, and it has taken on a new meaning as a response to the profound changes going on in our time. On the ideological level, the belief in progress, at least as naively understood in the nineteenth and in most of the twentieth centuries, has been dealt major blows, from which it has been unable to recover. The dream of the Enlightenment thinkers—that science and technology would be a means to the ends of social improvement and political emancipation—was short-lived. As Bertrand Russell and others have pointed out, science does not free humanity from its most violent passions; on the contrary, it may even fuel them. Technology has revealed itself to be an assistant to humanity in acts of the most horrible destruction and brutality. Scientific and technical progress has not prevented society from falling back into a state of incredibly cruel destruction and barbarity, of which the twentieth century had more than its share. Whatever gains in productivity have been achieved as a result of science and technology, we must conclude that they have not brought with them a concomitant improvement in moral standards and behavior.

Closer to the present, the tangible burdens of unrelenting technological advances have become more visible and, even as we strive to eliminate or contain them as much as possible, the unintended consequences of increasing intervention in the natural and social environment are here to stay. The shock wave created in the late 1960s and early 1970s by books such as Rachel Carson's *Silent Spring* (1962) or Meadows's *Limits to Growth* (1972) brought awareness of an ongoing environmental degradation and the onset of the much-vaunted risk society. While some of the environmental problems have been alleviated,

others have merely been transformed into increasing global inequalities. The demand for sustainability in interacting with the natural environment has, in conjunction with technological improvements, led to some beneficial results, although the final verdict as to where we now stand remains inconclusive. What has changed, however, is the perception of risks. The environmental agenda today is dominated by the major theme of global climate change and its anthropogenic origins. The threat it poses is quite serious since it represents the unpredictable: for extreme changes in weather and for extreme oscillations of climate. It spells unknown variability, both locally and regionally, and is imbued with a sense of human impotence. Faced with these unknowns, the only valid prediction seems to be "to expect the unexpected"—which hardly offers a solid basis for future interventions.

When Albert Camus spoke of the twentieth century as the century of fear, he had in mind primarily the horrors of the totalitarian regimes and the growing arsenal of weaponry, which was rapidly gaining the potential to wipe out humanity. Yet, seen in the light of the more recent past, fear has hardly diminished, although its form and shadowy profile have changed. It is no longer the one big catastrophe, caused either by the military or by nature's reaction to human intervention, which looms large on the horizon. Fear is now induced in small but all-pervasive doses. Much of the potential and actual risk is invisible. Negative consequences may be delayed and it is hardly seen as a consolation that never before in history has one had as good a chance of living longer. The suspicion lingers on that many of the latest scientific and technological developments appear to come with potential risks. With the real achievements of science and technology constantly overshadowed by potential risks, the ideological void is palpably waiting to be filled.

On the substantive-organizational side, the impact of science and technology on our lives is even greater. The large sociotechnical systems that were the pride of modernity are still with us, although they have acquired a bewildering complexity. Due to the unabated and worldwide spread of the power of computers, these systems have been partly decentralized and continue to promote processes of globalization. Jobs are outsourced to less developed countries where the percentage of a technologically savvy, highly skilled labor force is on the increase. The world of the factory, characterized by planning, control, and hierarchy and in which bulk material was processed and production-optimization strived for, has yielded in part to a high-tech world based on the processing of information. This new world is characterized by flattened hierarchies, by technologies depending upon other products and other technologies, by missions, by teams, and by cunning. Operations once handled by people are now handled by software. Adaptation to an ever-changing environment reigns supreme.[14]

With the shift from the state to market forces, national boundaries have not only become easier to cross, but this may now function as incentive or obsta-

cle for the creation of jobs and for increasing market shares. While the modern, pre-World War II managerial and engineering approach associates management with large manufacturing firms, the post-World War II approach associates management with projects that introduce new technological systems, such as computer networks and urban highways. They are no longer committed to maintaining a system for the mass production of standardized items. They tolerate and even embrace heterogeneity. They expect discontinuous change and brace themselves to manage innovation on a day-to-day basis in a world of complexity. Thomas P. Hughes has juxtaposed the characteristics of what he calls modern and postmodern project and technology management, and the comparison offers a striking contrast. Modern and postmodern project management excels in hierarchical and centralized control mechanisms and structures, tightly coupled systems, and homogeneity. Technology management relies on an often horizontal networked control, which is loosely coupled and thrives on heterogeneity. Heterogeneous agents control this technological culture, but this can no longer be exerted in a centralized mode. The best that such agents can do is to monitor the complex development of technology. These agents include industrial corporations, research laboratories, academia, the military, local and national governments, and "the will of the people."[15]

The changes on the substantive-material side are far greater still. The term technoscience (which appears more frequently since the 1980s) is often employed to capture the sense in which many scientific discoveries are closely related to new technical instrumentation, which are in turn the result of scientific knowledge, yet that can spread across various scientific fields and thereby achieve similar gains in productivity, as has been the case with industry. The French historian of technology Marc Bloch spoke of the creative force of the created object (*la force créatrice de l'objet créé*);[16] today we may note that this creative potential unfolds initially within the laboratory. This creative force is itself subsequently transformed in order to enter the market in a customized, often miniaturized, and highly fungible form in which it is fitted into one of the many distributed networked systems, which are heterogeneous and complex. And yet the term *technoscience,* while pointing to the strong coupling between "knowing what" and "knowing what for" (with the latter perhaps taking precedence), fails to capture one of the most salient characteristics of the new regime we have entered.

This shift of regime is marked by a profound transformation of both the technology itself and the context in which it works. It is a shift in scale that marks a shift in time and space, that makes possible new forms of time management, and that opens up new sites as a result of its functioning: sites that it then uses in the course of its functioning. It can perhaps best be summarized as a shift from exotechnologies to endotechnologies. Technology as it has existed since time immemorial, which enabled our ancestors to survive, has been commensurate in scale with that of the human habitat. Even when the sheer

reach of the human habitat was vastly extended—with the use of such modes of transportation as ships, cars, and airplanes—the goal of technology was to serve the function that archaeologists and anthropologists insist upon: to enlarge the biologically restricted human reach in its immediate and geographically extended environment. Such exotechnologies have enabled us to cross larger distances in less time; they have also allowed for the mass production of artifacts as well as for the construction of vast infrastructures for a variety of purposes, from growing, transporting, and conserving food and other products to living in growing comfort in a variety of climates.

The new regime of endotechnologies—biotechnologies and nanotechnologies together with information technologies and other enabling, symbolic technologies—is extending the scale of the human-built world down to that of infinitesimal living organisms and within matter itself. It transforms the management of time in the sense that those genetic mechanisms which, for instance, induces the growth of plants, can now be reversed, while natural aging processes can be speeded up or delayed. Electricity once allowed us to extend our use of daytime and indeed to turn night into day. This same effect is now made possible by our intervention into the circadian rhythm and by our switching genes on and off. Endotechnologies transform space by opening up living organisms and by turning them into the site of intervention. Living organisms and the creation of life, and the dynamics of growth and decline at different levels in the hierarchy of living matter, all these make possible novel forms of time management.

In 1959, at the annual meeting of the American Physical Society, Richard Feynman gave his classic lectures "There's Plenty of Room at the Bottom," about the prospect of manipulating objects on a small scale; he understood with astonishing foresight that the molecular structure of matter would become another prime site for new endotechnological procedures. Individual atoms can now be assembled and reassembled at will. New properties can be designed to build new materials. The "creative force of the created object" at work here comes from the growth of computers, which has enabled us to generate, process, and retrieve data on an unprecedented scale. This creative force is inherent in technical devices like the polymerase chain reaction (PCR) allowing the mass sequencing of genes. In the words of Paul Rabinow, "PCR is more than the possibilities of its applications. It possesses the quality to enable new events."[17] Many other methods and devices, and instruments and instrumentations exist, which all work together to make possible new events on unprecedentedly small scales. The growing inter- or transdisciplinary convergence of mathematics, biology, physics, chemistry, information technology, and statistics, brings approaches and methods to bear on commonly defined problems. Biology is taking great strides toward becoming integrative starting with the molecular level.

These developments, while being greeted enthusiastically by the scientific community, also create a lot of unease in the wider society. They raise such

questions as what it means to be human, who defines what is "natural," and what is considered "cultural." By extending the impact of technologies not only toward the environment, but by directing them inside living organisms, science has given rise to anxiety equivalent to the wonder it has inspired. With every new scientific and technological advance the number of options increases, yet it is impossible to foresee many of the consequences. Uncertainties abound and have become inherent to the process of producing new knowledge. The view of the future, as we have seen, has become fraught with uncertainties. There is, however, no turning back. As the number of potential future options grows, the number of escape routes diminishes. Fundamentalism, whether or not religious, remains one of the few alternatives, but its appeal is limited. The utopia of modernity has become exhausted, since the promises of modernity have been partly fulfilled. But when desire and reality do not match, discontent remains. We have to move forward toward a highly uncertain future—but how?

This is where the concept of innovation enters to fill the current void. Innovation signals the emergence of something new that is already present, but that is only partially recognizable. It may bring into focus the otherwise invisible links that bind together key concepts in a changing web of meanings. I am drawing here on the seminal work of Raymond Williams. When examining the transformation of culture, Williams discovered a curious interdependence or mutual reflexivity in the relationship between concurrent changes in language and society. He found that the word culture itself, like other key words such as class, industry, and democracy, had acquired its meanings in response to the very changes he meant to analyze.[18] The quest for innovation is such a concept, a term that fills a void at the intersection of the changes just analyzed.

Contrary to Bruno Latour's proposition that "We have never been modern,"[19] we are all modern today. And contrary to other postmodern beliefs, we are condemned to remain modern for some time to come. But modernity is no longer a program that will deliver—it has already delivered the building blocks, the institutions and structures we use. It fails to respond to expectations. It is no substitute for the belief in progress that served to underpin modernity until it collapsed under the weight of the hype it carried. With the future open, the challenge lies in the belief that worthwhile novelty will emerge with power sufficient to generate further worthwhile novelties, which will in turn lead to further economic growth and well-being is inevitable. This process should be sufficiently open to incorporate human values, like forging sustainable links to the natural environment or furthering education as a means of social inclusion. There are other strongly held values that have emerged, such as the value attached to security. But how to translate such values and their internal contradictions into a concept that will fill the void? The only other concept (or Denkfigur in the sense of Ludwik Fleck) that would offer a credible alternative is evolution. Taking the concept out of its original biologic domain of meaning

and transferring it metaphorically to the social and cultural domain, however, has proven to be extremely tricky.[20] Moreover, evolution, after having stripped the world of divine intervention, also leaves no room for human agency.

Innovation is a concept that crosses domains easily. It can take up residence in the cultural domain and in social organizations, indeed in every field in which human creativity flourishes. Innovation signals the positive direction where the unknown is to be found and it is therefore reassuring. In contrast to the concept of technology, innovation cannot be transformed into an object since it is a process, amenable to action and interaction, even if it carries its own load of uncertainty. But there is the chance that opportunities will outweigh whatever negative consequences the future has in store.

The impact on society and on the changes that will be introduced, especially through the next wave of the so-called convergent technologies, bio-, nano-, neuro-, and infotechnologies, will be profound. An abstract goal of innovation might be the "enhancement" of the human self. The profound and pervasive sense of unease regarding biotechnologies is likely to persist for some time. Human reproductive technologies, for example, are viewed with suspicion, as they threaten to upset kinship networks regarded as "natural" although they constitute in reality a mixture of biologic predispositions and variable social arrangements. Beyond the specifics of each case, there is an appeal for immutable values that will prevail amid a sea of changes. Yet, as history demonstrates, not every slippery slope is necessarily perilous, and values, however immutable they might appear, are subject to change in accordance with other changes in the society at large. Caught between the understandable wish to resist and to preserve the given order and the prospects of a new but largely unknown, hybrid order, the rallying cry is to move forward. This is the real meaning of being condemned to be modern. Innovation is the rallying cry and the promise of a new order to come, since at least it indicates the way that should lead there.

The meaning of innovation is affected by these processes as well. It is no longer, as Schumpeter in his classical analysis at the beginning of the twentieth century saw as "merely" a recombination of known factors that enables the entrepreneurial individual to gain a decisive advantage over the competition. Important and widespread as this recombinatorial form of innovation remains, a more extended notion of innovation, based on the potential of "radical" novelty and therefore embracing the uncertainty inherent, has emerged. As early as the 1970s, the economist G. L. S. Shackle spoke about "essential novelty" as idiosyncratic of an evolutionary approach in technosocial innovations that includes openness toward an unknown future.[21] Seen from an economic perspective, innovation presupposes contingencies and choices that transcend a recombination of what already exists.

Innovation fills the void that arises out of the genuine uncertainty inherent in the process of innovation itself. Paradoxically, it is this due to circularity—

or modern reflexivity—of innovation that it has the ability to fill this void. It is not an unmoved mover behind the impersonal forces of a technocratic society, as it might have been the case not too long ago. Technocracy itself, as a recognizable structure, is being undone by innovation—only to be reconfigured as a widely dispersed, interlocking form of governance in which not only corporate actors and governments, but also civil society, interact in a conflict-ridden struggle for the newly emerging global order. Innovation is the only credible response currently available for coping with the uncertainty it has helped to generate. It is credible in the sense that it does not preclude plurality, diversity, or variation. On the contrary, it invites and thrives on them. Innovation—although its direction is heavily biased toward scientific-technological advances—does not preclude manifestation in other domains: social innovations, for instance, which might bring about other forms of governance, with the task of integrating the current skepticism and prevailing unease with regard to certain technological innovations. It does not preclude the possibility of new forms of cultural innovation, with the arts confronting the way in which the disturbances emanate from the latest run of feasible scientific-technical breakthroughs.[22] Innovation is called for everywhere—and not precluded anywhere. This is why it is credible.

Innovation invites human agency and depends upon it—where would it come from otherwise? Technological developments merely provide opportunities, and it is up to us, individually as well as collectively, to act upon them. It does not predetermine any specific end result. The only determinant it resolutely insists upon, is the option of change. It plays with the ambiguities entailed by embracing change when the goal is not fixed, but reassures us that human action may shape what is to come. Dealing with risks? No problem, since you may adopt the precautionary principle. You may also choose not to espouse the apocalyptic warnings contained in the "risk-society" and instead opt for a "modern" risk culture as it is embodied by the global financial markets. These are institutions that depend not only upon infrastructures and material resources, but have also adopted a specific risk culture, "an entrenched set of practices of market configuration, technological development, social-group construction, and notions of authority, expertise, and creativity which combines modernity's ambition to know with the market's ambition to commodify".[23] The argument of choice, so deeply entrenched both in neoliberal economics and liberal democracies, has benefited the empowerment of consumers, without always assuring that the preconditions for exerting choice are being met.

In brief, the concept of innovation is closer than other concepts, like the "knowledge society" (which invokes counterconcepts, e.g., ignorance and the right not to know), to the continuity of an iterative modernity, punctuated as may be the case by relapses into recurrent crises and into periods of ardent criticism. Innovation contains a self-fulfilling promise: that only innovation can

provide us with a way to cope with innovation. This circularity is backed by past achievements and extends toward a fragile future, even while promising to transcend the present.

Cultures of Technology

Culture matters—this has been one of the most often-heard messages. It matters in its attempts to explain why economic opportunities have been seized in one country or region, and why economic failures have occurred in another. It matters not only for economic development, but also for political development. It promotes change—or impedes it.[24] It matters when corporations with different organizational cultures merge or fail to do so. With organizations increasingly moving in global environment, they are well-advised to broaden their cultural range and to question the assumption that their concepts are universally valid. In the field of organizational learning, for instance, a shift has occurred toward a concept of organizational culture as the unit in which learning occurs. The culture of an organization is said to be pivotal to understanding how a particular organization adapts to ongoing changes. It shapes perceptions of past and current events. The emphasis is on shared conceptions of what needs to be learned, how it is to be learned, and why.[25] Culture is understood here in its most encompassing sense: a shared scheme of interpretation that enables the organization to cope with change.

Culture matters—and indeed it permeates an enormously wide range of social activities. It binds together communities or sets them apart. It makes communities different from each other, shaping their interaction not only among members, but between the community and outsiders. It is linked to innovation in often unforeseeable ways in the sense that it can be predisposed to finding certain innovative solutions to a problem while eschewing others. In an interesting case study, the economic historian Avner Greif has analyzed the relationship between culture, innovation, and the institutional structure. Integrating game-theory with sociological concepts and basing his work on comparative historical material, he examines cultural factors that have led two premodern societies, one from the Arab and the other from the Latin world, to evolve along distinct trajectories of institutional structure. Based upon historical records from the late eleventh century, Greif demonstrates that the two societies of medieval traders, the Genoese and the Maghribis, the latter, Jewish merchants living in a Muslim society, were both involved in mercantile relationships all over the Mediterranean. They employed comparable naval technology and traded in similar merchandise. The success of their trade depended to a large extent on their ability to mitigate the provision of services required for handling a merchant's goods abroad. A merchant could either provide these services himself or, as was most often the case, employ overseas agents to handle

the merchandise, since this was a time-consuming endeavor. Employing agents was efficient, since it saved time and removed the risk of travel. Yet without supporting institutions, agency relations could not be established due to the potential of embezzlement.

Culture matters—since the Genoese society was much more individualistic, while the Maghribis were collectivistic. Their strategies (which Greif also analyzes in game-theoretical terms) differed accordingly. The results touch upon different patterns of wealth distribution and their consequences for the political organization of the society as well as upon the way in which the two societies coped when they expanded their trade to areas previously inaccessible. The Genoese responded in an "integrated" manner, the Maghribis in a "segregated" manner. Both projected their cultural beliefs onto the new situation. But their cultural beliefs did not specify what the best response would be. The "segregated" response culminated in merchants from each society preferring to hire agents from their own society, while in the "integrated" response, there was no preference. Constrained by the same technology and environment and facing the same organizational problems, the two societies had different cultural heritages and social and political histories. In one case, however, collectivistic cultural beliefs led to an innovative response consisting in investments in information, segregation, and to a stable pattern of wealth distribution, while in the other case, individualistic cultural beliefs induced different kinds of enforcement mechanisms, a vertical social structure, a relatively low level of information, and to economic and social integration and wealth transfer to the relatively poor. In the end, both systems were efficient in the sense that they produced innovations, although in different ways, and each had to pay a price for its relative strengths and weaknesses. Nevertheless, Greif concludes, the individualism displayed by the Genoese medieval society may have cultivated the seeds that contributed to later economic and technological development and to the so-called rise of the West.[26]

To approach technology from a cultural perspective it is, therefore, at once self-evident and highly demanding: self-evident, because technology is one of the most consequential cultural practices to have evolved since the beginnings of humanity. The extension of human capacities which allowed humans to overcome and to extend their given biologic constraints, as well as those of the natural habitat in which they found themselves, is truly impressive. Merlin Donald has drawn attention to the rise of symbolic technologies, the invention and manipulation of external symbols that have changed the way in which we think, remember, and experience reality.[27] This rise of symbolic technologies has triggered a powerful cognitive transition (the first was the origin of language), liberating consciousness from the limitations of the brain's biologic memory system. Symbolic technologies have opened the gateway to allow the merging of symbolic virtuality with material reality. They are wired together in a distributed cognitive system that gives rise to cultural possibilities. Human con-

scious capacity, distributed over the entire society, is a resource that limits the rate at which culture can accumulate knowledge and determines what kinds of representational systems a culture can successfully construct and maintain.

But to approach technology from a cultural perspective is also highly demanding: highly demanding since it requires one to confront both technology's materiality and the cultural system of meaning with which technological practices are invested. Such a perspective raises questions as to the identity of the makers, controllers, facilitators, and shapers of technology. The enormous impact of today's information and communication technologies, including their powers of visualization, is linked to their dissemination throughout society. They have greatly facilitated the ongoing processes of globalization—with all of its downsides. New groups of users have gained access to these technologies and continue to take them in unexpected directions. The role of the nation-state as an advocate of technology is also in flux, although the state, by maintaining its monopoly over violence, remains a steadfast and generous supporter, especially of military technology. Globalization and its impact upon domestic arrangements also leads to a growing demand for transnational rules and regulations, which affect in turn the conditions under which cultures of technology are either stifled or allowed to flourish.

What is gained by conceiving of technology not just as an ensemble of artifacts or complex sociotechnical systems, but as *culture*? If we take the meaning of culture in its strictest anthropological sense—although there is no commonly agreed-upon definition of culture in anthropology either—we can say that culture does not exist independent of social interactions. Culture is about social relations with meanings attached to what people believe, do, and how they relate to each other and to their environment. Technological culture includes technical artifacts as an integral part of this web of significance. The web of significance that human beings have spun themselves, and in which they are suspended, following Clifford Geertz's description,[28] makes sense only when it is linked to human agency, intentions, interactions, results, and to the ensuing effects and transformations. Technology enters in an immensely practical way as a mediating object, acting upon social interactions and relationships and being acted upon. It does so by providing a "tight coupling of causally related elements" (Niklas Luhmann) rooted in their material and symbolic base. Technology may dispense with decisions, and it may replace the arduous process of consensus finding, because decisions have been taken before and have been transformed into such a "tight coupling of causally related elements." This is how technology works. Within the frame of these couplings, automatic, and hence predictable sequences, are guaranteed—but they still mediate some kind of social interaction or purpose. When the coupling is extended, the use and the power of symbolic technology comes from both their externalization and from being shared culturally across the multitude of minds, each dependent upon the other to further enhance the potential embodied by technology.

Cultures of technology are about arrangements. To speak about different cultures of technology breaks down the distinction between the material tool or its built-in technological efficiency, and the social organization, including the individual user and their social interactions. Cultures of technology are about shared meanings. Culture organizes practices. The processes and the range of ways in which this is done also matters. To focus on cultures of technology does not imply a neglect of the subtle impact that technology has on our lives, nor does it ignore the first steps in the genesis of emerging new technology. Rather, the emphasis is on what John Pickstone (in the alternative frame he has developed to take a fresh historical look across the entire spectrum of science, technology, and medicine), calls "ways of doing."[29]

Technology works—and we expect it to work. It works on different levels and in different ways. They work through the tight or loose coupling of the elements that make up a technological system. They work through the ways in which people organize their work and through the division of labor in manufacturing or in service industries. They work by mediating social interaction. But they also work in a very powerful way by generating symbolic and cultural meanings. Any comprehensive account of technological innovation, as John Pickstone writes in this book, must allow for these meanings, including their supposed derivation from science. If we can see how the various elements of technology—from long-standing and usually traditional crafts, by way of systematic invention dating from about 1870 and demanding considerable social organization and education, to the present situation of high-tech, high-science complexity spreading across many sectors with the increasing use of computers at its base—fit together in history and our present, then we will have a good model for understanding technological innovation, including its cultural meaning.

Cultures of technology should therefore prepare us to understand where the quest for innovation comes from, pushing us forcefully to go far beyond any imagined "endless frontier." Innovation is no longer a goal, since it has, by its very nature, espoused a striving for the unpredictable and the unknown. Perhaps it has become a means—however, it can only constitute a tentative attempt to cope with the idea of a future that has become full of surprises.

The idea of innovation, as I have argued, is currently filling the void of negotiating the future. One of its strongest bargaining chips is scientific and technological innovation; another, which is closely associated with this innovations is that of risk. Contrary to its initial meaning of trying to put the future into the service of the present, by showing that risks can be measured the concept of risk has become confounded at present with that of danger—negative consequences of unknown proportion and substance to be avoided but that cannot be calculated. Modern risk implied daring in the sense of putting up an asset for disposition against the chances of another, unknown, but higher gain. Modern risk was underwritten by the belief that, at least to some extent, alternative futures could be devised. Over the centuries, technology emerged as

one of the most powerful means of shaping this belief into some degree of tangible planning; it therefore was able to control the future.

Today, the modern management of risk, notwithstanding the many unresolved problems, has become highly professionalized and, as we have seen, is thriving in one sector that has transformed it into a business of its own, the management of financial markets. But technology, often lumped together indiscriminately with the concept of a unified science or seen as merely applied science, has become associated, if not tarnished, with the negative consequences they have also had on the social fabric of modern societies. The confidence in the achievement of sustainable technological progress is a precarious one, punctuated time and again by scandals involving the political management and regulation of risks associated with technological advances. The quest for ongoing innovation promises a way out. Its very open-endedness suggests a new flexibility and may point in the direction of improved and safe technology. It may gesture toward collective learning processes, which span the public and private domains and may bring with them social innovations of a kind as yet unknown.

The goal of this volume is to identify cultures of technology as a way of working across the entire societal spectrum, linking the technical intricacies with the requirements of the social and economic fabric of societies, uncovering the meanings that people attribute to how technology works, including how it affects their lives. They cover a wide range of human experience in the project of promoting certain cultures of technologies or confronting their consequences. One part of this experience is gender-specific. Only the culture of war seems to be a human constant over time, although it also alters its manifestations and increases the power of its destructive force. As will become abundantly clear, speaking about cultures of technology never means speaking about technology alone. Admitting that technology can also be vulnerable reveals its entangled interdependence with the wider society—for better or for worse.

Contributions to this volume

The first section of this volume explores the relationship between culture, technology and innovation. Tom Hughes defines these key terms and analyzes the various forms that innovation can take in an increasingly technology-based civilization. Over the course of history, national and urban cultures have provided different means of expression for the drive to innovation that have shaped how we manage to live in today's complex world. The history of past innovation holds lessons for today, uncertain as its outcome may be.

This is followed by Rosalind Williams's intriguing case study of some of the unintended consequences of innovation. Drawing her empirical material from a detailed analysis of innovation processes at MIT, Williams shows the

inseparably link of technological and social innovation and shows how the culture of an organization is created. This raises a number of deeply disturbing questions about the balance between innovation and its effects. In the words of one of the contributors, which echos the experience of many people caught in the whirl of innovation, what is needed in order to "create change" is time. In Williams's succinct formulation, innovation produces a crowded world in which it is progressively more difficult to find the time to produce innovation.

This section concludes with Wiebe E. Bijker with his analysis of the vulnerability of today's technological civilization. Such vulnerability, if treated with the intellectual respect it deserves, is perhaps a prerequisite for the quest for innovation. To live in an open, changing, and innovative culture, Bijker claims, we have to be prepared to pay the price of vulnerability. Bijker proposes a model of vulnerability that sees it not only as a threat to our survival, but also as hope for the future. He revisits the literature on risk, arguing that vulnerability and risk are related. Vulnerability refers to a system's ability to anticipate, resist, and possibly recover from events that could reduce its functional integrity, while the notion of risk is outcome-oriented. The overwhelming feeling is often that of the extensive vulnerability of our societies. Bijker urges us not to yield to the obsession with safety and control.

The next section renders an account, both theoretically and empirically inspiring, of how cultures of technology can be seen at work in a gender-specific way. Delphine Gardey takes us back to the tumultuous changes wrought by the new technology, namely of the technological and social changes introduced between 1890 and 1930 in the business sector in France. She elicits the processes by which technologies and artifacts are gendered in the context of offices. Offices, which initially were defined as male-dominated, becomes the arena for a requalification of both the men and women working there and the technological advances intended to make their work more efficient. Gardey uncovers the mechanisms through which the gendering of objects took place and shows how social and cultural roles were redefined by a technology itself subject to the same processes. In the end the true power of technology seems to reside in its invisibility. It is time to shed light on this gender bias, in order to better understand the mechanisms upon which a particular technological culture is based, as well as its wider implications.

Taking up the same theme, Judy Wajcman reflects upon innovation and cyberspace. She explores the lingering suspicion that existing societal patterns of inequality are being reproduced in a new technological guise; even though cyberfeminists have been excited by the possibilities that cyberspace offers women. She brings out the inherent tension in much contemporary writing, between the utopian and the descriptive, contrasting this with a more sober account of information technology, electronics, and communications sector as still very much a male-dominated industry within which women enjoy only limited career prospects. Any emancipatory politics of technology needs to be

embedded in a technological culture aware of its biases and shortcomings. It requires more than hardware and software—it needs conscious and responsible human agency.

In the next section John Pickstone provides us with a fascinating historical account that undermines the popular usage of the word science, at least in the English-speaking world. He proposes an alternative framework for understanding historical processes and for analyzing innovations in science, technology, and medicine, one that does not rely on the primacy of science. Drawing on his book, *Ways of Knowing* (2000), Pickstone links biographical elements comprising the experience of people with natural history, analysis, and experimentation as embodying different ways of knowing. Turning toward the contemporary scene in facing complex technological problems and the increasing demand from the public for greater involvement, he argues convincingly that we should use several forms of analysis to uncover other ways of knowing. Pickstone's analysis is a refreshing voice that proposes how an emerging culture of technology should structure its debates in order to further public interest.

Jean-Jacques Salomon discusses the culture of war, its technological prowess, and the changing role played by scientists in the continuing unfolding of this human drama. Salomon takes us through some of the historical developments leading up to World War II and culminating in the development of the atomic bomb. He lays bare some of the most acute conflicts. Sadly, the aftermath of 11 September 2001, has not witnessed any involvement on the part of scientists and engineers in their ongoing attempts to forcefully confront an elusive enemy and to maintain military world dominance by relying upon scientific and technological innovation. Thanks to the ongoing, indeed growing involvement of science and technology, of scientists and engineers, in warfare, Salomon concludes that the twenty-first century may go on to challenge the title of the century of fear, as conferred upon it by Albert Camus.

The last section on the cultural contexts in which innovations are adopted, transformed, or rejected, brings together national case studies. One such case study by Patrick Kupper, deals with the rise and demise of nuclear technology. In the case of Switzerland, as in many other countries in the mid-1960s, nuclear energy had a lot to offer. He develops an argument about the history of nuclear energy in Switzerland, based on three hypotheses: nuclear power plants were commercially introduced without having achieved an adequate level of technical maturity; the rise of nuclear power was influenced by cultural factors; and the demise of the nuclear power economy after 1970 must be seen in relationship to its prior rapid rise. What emerges is a sophisticated eyewitness account of the way in which innovations unfold—and of the way in which they may falter, turning prophecies of a wonderful future into the incarnation of a technocratic past.

Hans Ulrich Vogel discusses a broadly based intra- and intercultural comparison, which scrutinizes the salt and mining industries in premodern China

and compares them with the situation in premodern Europe. Although traditional Chinese culture was rich in innovations, there were also limitations that prevented the unfolding of this potential. What is fascinating to observe in retrospect is the long-lasting impact that cultural differences, the role of the state, and differences in social status had when China is compared to Europe. Mining and smelting techniques, for instance, exhibited many modern characteristics. They were enhanced by mechanization, which stimulated the combination of theory and practice. Being risky, they were in need of large amounts of capital. In Europe, meanwhile, the incipient social solidarity and security systems in many mining communities were exemplary for their time, displaying a closer fit between technology, culture and social structure.

The volume closes with an epilogue in which Joachim Nettelbeck, administrator of the Wissenschaftskolleg zu Berlin, reflects on the nature of organizations that become "spaces for translation." He discusses an Institute for Advanced Study in which scholars from different scientific disciplines come together for a limited period of time expecting the unexpected to occur. This is made possible, Nettelbeck argues, through the organization of "translation," in which innovative insights and outcomes emerge as a result of novel interactions, the encounter of different disciplines of science and culture, and of different practical and theoretical concerns. Network organizations and their cultures contain considerable potential for innovation, for whose emergence, however, the constituent elements have to be closely observed and designed.

With any luck, this volume will also turn out to be a space for translation, in which the ubiquitous quest for innovation is linked once again with the concerns, interests, and aspirations harbored by many of us as we approach today's technology that though vulnerable, nevertheless holds the key for a better society.

Notes

1. Dennis L. Meadows et al., *The Limits to Growth* (New York, 1972).

2. Helga Nowotny, "Vergangene Zukunft; Ein Blick zurück auf die 'Grenzen des Wachstums,'" in *Impulse geben—Wissen stiften. 40 Jahre Volkswagenstiftung* (Göttingen, Germany, 2002).

3. Yaron Ezrahi, "Science and the Postmodern Shift in Contemporary Democracies," in Bernward Joerges and Nowotny, eds., *Social Studies of Science and Technology: Looking Back, Ahead* (Dordrecht, Netherlands, 2003), 63–75.

4. Brian W. Arthur, "Increasing Returns and the New World of Business," *Harvard Business Review,* July–August 1996, 1–10.

5. Jens Beckert, *Beyond the Market. The Social Foundations of Economic Efficiency* (Princeton, 2002); Joseph A. Schumpeter, *The Theory of Economic Development. An Inquiry Into Profits, Capital, Credit, Interest, and the Business Cycle* (Cambridge, Mass., 1934 [original: *Theorie der wirtschaftlichen Entwicklung* (Leipzig, Germany, 1912)]).

6. Peter L. Bernstein, *Against the God. The Remarkable Story of Risk* (New York, 1996).

7. Nathan Rosenberg and L. E. Birdzell Jr., *How the West Grew Rich: The Economic Transformation of the Industrial World* (New York, 1985), 265, quoted by Lewis M. Branscomb, "Techno-

logical Innovation," in Neil J. Smelser and Paul B. Baltes, eds., *International Encyclopedia of the Social & Behavioral Sciences* (Amsterdam, 2001), 5: 15498–15502.

8. Branscomb, "Technological Innovation."

9. Richard R. Nelson, ed., *National Innovation Systems: A Comparative Analysis* (New York, 1993), 4.

10. Michael Gibbons et al., *The New Production of Knowledge: The Dynamics of Science and Research in Contemporary Socities* (London, 1994).

11. Leo Marx, "Technology: The Emergence of a Hazardous Concept," *Social Research* 64, no. 3 (1997): 965–88.

12. Daniel Webster, *The Writings and Speeches of Daniel Webster* (Boston, 1903), 105–107.

13. Ibid.

14. Arthur, "Increasing Returns and the New World of Business."

15. Thomas P. Hughes, *Rescuing Prometheus* (New York, 1998).

16. Ulrich Raulff, *Ein Historiker im 20. Jahrhundert: Marc Bloch* (Frankfurt am Main, Germany, 1995).

17. Paul Rabinow, *Making PCR: A Story of Biotechnology* (Chicago, 1996), 169.

18. Raymond Williams, *Culture and Society: 1780–1950* (London, 1958 [1983]), xiii–xviii.

19. Bruno Latour, *We have never been modern* (New York, 1993).

20. Donald T. Campbell, "On the Conflicts Between Biological and Social Evolution and Between Psychology and Moral Tradition," *American Psychologist* (December 1975): 1103–26. See also Campbell, "Variation and Selective Retention in Socio-Cultural Evolution," *General Systems* 14 (1969), 69–85.

21. G. L. S. Shackle, *Decision, Order, and Time in Human Affairs* (Cambridge, 1969).

22. Nowotny, "Wish Fulfillment and Its Discontents," *EMBO reports* 4, no. 10 (2003): 917–20.

23. Stephen Green, "Negotiating With the Future: The Culture of Modern Risk in Global Financial Markets," *Environment and Planning D: Society and Space* 18 (2000): 77–89.

24. Harrison E. Lawrence and Samuel P. Huntington, eds., *Culture Matters: How Values Shape Human Progress* (New York, 2000).

25. Meinolf Dierkes, Ariane Berthoin Antal, John Child, and Ikujiro Nonaka, eds., *Handbook of Organizational Learning and Knowledge* (Oxford, 2001), 922.

26. Avner Greif, "Cultural Beliefs and the Organization of Society: A Historical and Theoretical Reflection on Collectivist and Individualist Societies," *Journal of Political Economy* 102, no.5 (1994), 912–50.

27. Merlin Donald, *A Mind So Rare: The Evolution of Human Consciousness* (New York, 2001).

28. Clifford Geertz, *Interpretation of Cultures* (New York, 1972), 5.

29. John V. Pickstone, *Ways of Knowing: A New History of Science, Technology, and Medicine* (Manchester, 2000 and Chicago, 2001).