From: A. Borgmann, Technology & the Character of Contemporary Life (Chicago: UCP, 1984).

1 Technology and Theory

The advanced technological way of life is usually seen as rich in styles and opportunities, pregnant with radical innovations, and open to a promising future. The problems that beset technological societies are thought to be extrinsic to technology; they stem, supposedly, from political indecision, social injustice, or environmental constraints. I consider this a serious misreading of our situation. I propose to show that there is a characteristic and constraining pattern to the entire fabric of our lives. This pattern is visible first and most of all in the countless inconspicuous objects and procedures of daily life in a technological society. It is concrete in its manifestations, closest to our existence, and pervasive in its extent. The rise and the rule of this pattern I consider the most consequential event of the modern period. Once the pattern is explicated and seen, it sheds light on the hopes that have shaped our times, on the confusions and frustrations that we have suffered in our attempts to realize those hopes, and on the possibilities of clarifying our deepest aspirations and of acting constructively on our best insights.

Concrete, everyday life is always and, it seems, rightly taken for granted. It is the common and obvious foreground of our lives that is understood by everyone. Therefore it is almost systematically and universally skipped in philosophical and social analysis. But if the determining pattern of our lives resides and sustains itself primarily in the inconspicuous setting of our daily surroundings and activities, then the decisive force of our time inevitably escapes scrutiny and criticism. I want to argue that this is in fact so, and not only because everydayness in general seems inconsiderable but because of the particular way in which the ruling pattern of our time arose and came to be articulated.

The pattern of which I have been speaking inheres in the dominant way in which we in the modern era have been taking up with the world; and that characteristic approach to reality I call (modern) technology. Technology becomes most concrete and evident in (technological) devices, in objects such as television sets, central heating plants, automobiles, and the like. Devices therefore represent clear and accessible cases of the pattern or paradigm of modern technology. Giving these claims conviction will occupy us for much of the book. But the note of alarm in the foregoing remarks and their abstract and perhaps peremptory tone as well as the unusual focus of the perspective that they advocate make it advisable to provide an early illustration of the device paradigm. Surely a stereo set, consisting of a turntable, an amplifier, and speakers, is a technological device. Its reason for being is well understood. It is to provide music. But this simple understanding conceals the characteristic way in which music is procured by a device. After all, a group of friends who gather with their instruments to delight me on my birthday provide music too. A stereo set, however, secures music not just on a festive day but at any time, and not just competent flute and violin music but music produced by

instruments of any kind or any number and at whatever level of quality. To this apparent richness and variety of technologically produced music there corresponds an extreme concealment or abstractness in the mode of its production. Records as unlabeled physical items do not bespeak, except to the most practiced of eyes, what kind of music they contain. Loudspeakers have no visible affinity to the human voice, to the brass or the strings whose sound they reproduce. I have little understanding of how the music came to be recorded on the disk and by what means it is retrieved from it. I have a vague conception at best of the musicians who originally performed the music; I may not even know how many there were, and in some cases I will not be able to distinguish or identify their instruments from the reproduction of their playing.

When we consider such a technological device and the things and practices that it replaces, varied and conflicting intuitions come to mind. What are the gains and what the losses in the rise of technologically recorded and reproduced music? If a consistent and revealing answer can be found to this question, does the finding have general significance? Is it an instance of a pervasive pattern? In the pursuit of an answer to these questions, we will have to pay attention to the sharp division between the commodious availability of music that a stereo set procures and the forbiddingly complex and inaccessible character of the apparatus on which that procurement rests. It is the division between the commodity, e.g., music, and the machinery, e.g., the mechanical and electronic apparatus of a stereo set, that is the distinctive feature of a technological device. An object that exhibits this central feature clearly is a paradigm of the technological device. I use "paradigm," however, not only in the sense of "clear case" but also for the pattern the clear case exhibits so well; and that pattern in turn can be drawn from various points of view and at different levels of abstraction. Obviously this definition of technology conflicts with many others that have been developed. It is helpful to consider these, and I will do so in Chapter 2. But it is not my purpose to establish the sense of technology that I have proposed as somehow superior or privileged. What the word "technology" should provide for this essay is a concept, a *conceptus*, in which the most helpful insights and experiences are gathered in a tentative, prereflective way.

Helpful for what? The chief concerns of this book are two, and they are interrelated as follows: The first is to provide a concise, illuminating, and, as far as possible, cogent description of the device paradigm. This description reveals a fatally debilitating tendency in the present rule of technology. But that aspect of its rule can be made intelligible only if we turn explicitly to those forces in our lives that are endangered by the rule of the device paradigm. I use "focal things and practices" as approximate terms for those forces. My second major concern is therefore with the nature of focal concerns. Here too an introductory sketch may aid the reader's orientation. A focal practice is one that can center and illuminate our lives. Music certainly has that power if it is alive as a regular and skillful engagement of body and mind and if it

graces us in a full and final way. Our daily and mundane endeavors are then centered around music and invigorated by it. In such a practice the musical instrument occupies a privileged place. In many cases it embodies a long tradition of a craft, of a method, and of a musical literature. In it the melodious power of the world is gathered concretely. And it challenges humans to develop and exercise the finest bodily movements of which they are capable. In this sense a violin, for instance, is a focal thing. These observations will again evoke a variety of responses. We may applaud the value of music and yet wonder if musical practice can have a secure, a consequential, and a widely shared place in a technological setting. Still, it may have become apparent that there is a crucial connection between the rule of the device paradigm and the destiny of focal concerns. The present essay, at any rate, is primarily concerned with the explication of the technological paradigm and the elucidation of focal concerns.

These two major tasks are taken up in more specific or subsidiary investigations. The first of the latter are preparatory and methodological. Since I regard "technology" as the most appropriate and helpful title for what is characteristic of our lives, it is necessary to take account of presently available theories of technology. And since I am urging a shift in philosophical attention and description, reflection is needed on what it means to describe, explain, and evaluate something. There is a particular need to take account of natural science both because it sets new standards of description and explanation and because it is a crucial, though poorly understood, contributor to the rise of technology. These matters are taken up in Part 1, "The Problem of Technology."

Part 2, "The Character of Technology," turns to the central task of describing the concrete features and idiosyncrasies of technology. Though I claim that these are usually and even systematically overlooked, it would be most unlikely, and no one would reasonably assume, that what is most characteristic and consequential in our time has been altogether missed or ignored. It is possible, however, that a failure of focus has deflected, confused, or limited social and philosophical analyses of technological culture. My task, therefore, is not to reject or deny such inquiries but to point out how their best insights are rendered more incisive and consistent when the technological pattern of our time is clearly seen. Moreover, the investigations of social scientists have collected many data which, however limited or one-sided in perspective, have a strong claim to objectivity and generality. The kind of description and analysis that I propose is, roughly speaking, in a phenomenological style, and such analyses often run the risk of being anecdotal and parochial. For these reasons the description of the device paradigm must be tested and elaborated against pertinent work in philosophy and especially in the social sciences.

I regard scholarship as essential to a serious and credible inquiry. Still I have made no attempt to exhaust the scholarly material. Technology is at the intersection of so many currents and disciplines that the literature has become

boundless in its extent. But the essential positions, I have found, appear to be limited in number. What can be expected from the treatment of scholarship is not exhaustiveness but a thorough consideration of some of the eminent and representative schools of thought and the possibility of extending fruitfully and consistently the major theses of the book to arguments and evidence that have been ignored. Though scholarship must be given its due, the esoteric features of its language and arguments are not needed in an essay of the present sort. Accordingly I have tried to write in a style that is accessible to any literate reader. I have tried to do this through simplicity of presentation and through the explanation and illustration of technical matters where the latter are unavoidable.

In Part 3, "The Reform of Technology," I turn to the focal forces whose predicament and dignity is what finally motivates my critique of technology. Here again, my concern in general is not unique. Just as there is an abundant literature devoted to the analysis of the technological society, so there is an abundance of pleas for the victims of technology and of reform proposals. But the lack of focus that I have claimed for the common analysis of technology infects the literature of accusation and reform more harmfully still. Since most writers fail to have a clear view of the pattern according to which we orient ourselves and take up with the world, their allegations are often misdirected and their proposals ineffective. The latter are so because they frequently play into the hands of what they oppose or they fail to connect with the real openings for reform.

Assuming that this essay accomplishes what it sets out to do, is it not one of social analysis and commentary? In what sense does it constitute a *philosophy* of technology? To begin with, I believe that there is no sharp dividing line between social science, or perhaps social studies, and philosophy. To be sure, this is to take philosophy in a sense which is not the dominant one in the modern era and is only now being recovered. It is a traditional one, however, and close to Aristotelian theory, to *theoria*, the calm and resourceful vision of the world.[1] *Theoria* was eclipsed with the rise of the modern period, and ambiguity befell all eminently theoretical endeavors. Language is negatively ambiguous if it exhibits a disorienting or debilitating plurality of senses. In the everyday world a pervasive negative ambiguity makes itself felt in the suspicion and diffidence with which ambitious questions and assertions are met.[2] Words of beauty are suspected of naiveté, words of salvation are thought to conceal egotism, words of profoundness are charged with obscurantism. The mere plurality of senses that attaches to every word is a prosaic matter, apparent in dictionaries, and normally counterbalanced by the resolving force of the context of discourse. But no such context seems to be at hand when weighty matters are at issue. Instead more and more claims pour forth, eroding and submerging all points of orientation.

Philosophers today try to gain firm ground and act on this ambiguity by turning to the antecedent and enabling conditions of thought, discourse, and

argument. Attention is directed not to what is claimed to be shown and seen but to the grounds and possibilities of claims in general. Philosophy is not concerned with theory in the sense of a steady view of the world but with metatheory, the conditions of visibility.[3] This seems to be a plausible move beyond the common level of confusion. In fact it turns out to be an inconclusive enterprise. But that does not permit us to set it aside. It is for now simply a fact that the predominant response to ambiguity is not a desire to be open for what speaks with simple and salutary authority but the desire to gain authority over ambiguity by getting hold of its controlling conditions. The pattern and context of this response will become clearer precisely when we first take the metatheoretical turn and then move on to its final analysis where its insufficiency and the region beyond it become apparent.

There is a spectrum of attempts at taking the measure of our times. At one end are the concerns with immediately pressing and empirically quantifiable issues; at the other we find considerations of a radical and reflective sort. The present study is philosophical in belonging to the latter extreme. Though it pays more attention to substantive and empirical concerns than philosophy typically does, at least in this country, the present study has to draw on many of the concepts, methods, and insights of mainstream philosophy to obtain a reflective and radical view; and to that extent it is philosophical in the currently received sense as well.

2 Theories of Technology

Proponents of science and technology can respond to flamboyant accusations and proposals with superior silence. Modern science provides principled explanations and modern technology effective solutions of the problems that have troubled the human race from its beginning. This, at any rate, is the prevailing view, and it has a measure of accuracy. And from that viewpoint critics and competitors who fail to attain scientific rigor and technological efficacy are disqualified at the start. The strength of this view cannot be overcome by a colorful tour de force. One must at least begin by meeting it punctually and carefully. To be sure, one cannot overtake science and technology by their own standards. But care and precision of argument can make an opening for a truly alternative and viable kind of discourse, and in that universe of discourse deeper concerns can come to the fore which are eclipsed by science and technology. It is for the sake of these final aspirations that this essay sets out in what may seem an overly painstaking way.

Before a theory of technology as a vision of the world can be advanced, then, we must reflect on the possibilities of such a theory. They are best approached by starting from the theories of technology that have been de-

veloped in the literature. Each of these theories is guided by a certain sense of technology. The most common can be circumscribed as applied science and engineering. It designates an area of much sober and salutary work whose practitioners are entitled to fair and judicious treatment. If the word is not used in this sense, that must be made clear.[1] In fact, technology as applied science and engineering is not a suitable title and guide for a theory of technology.[2] To begin with, the subject matter covered by that title suffers from an overarticulation of its parts and seems to leave no areas for fruitful philosophical inquiry.[3] It is the result of singularly principled and systematic efforts. No sorting out seems to be necessary. Take the case of medical technology. It would be nonsensical to ponder the laws and methods that surgical procedures, for instance, are based on. At best one would come back to the explicit knowledge of anatomy, biology, chemistry, and so forth from which surgical techniques derive in the first place. On the other hand, the reduction of a practically successful but theoretically opaque procedure to scientific laws, say, in metallurgy, is doing technology; it is not philosophical reflection about technology. The same holds true when we turn to the narrowly technological *context* of medical technology. There is voluminous and explicit knowledge on how medicine by way of insurance is connected to the economy, how by way of medical schools to the educational establishment, how by way of the AMA to politics, and so on. All these problems are at least attended to by well-trained specialists, and no field of inquiry is left for the philosopher.

At the same time, there is a common intuition that the realm of research and development and of machines is characteristic of our era. Any fundamental investigation that ignores that part of our world must appear quaint. But to bring out the significance of technology in this larger sense one must turn to a larger context, to the antecedents and consequences of applied science and engineering. Often technology is kept as a designation for that wider field of study and its findings. Technology in this broader and stronger sense competes with other titles that attempt to catch the character of our times.[4] As said before, the contest of titles should be decided by the criterion of fruitfulness.

Philosophy at its best has always been concerned to provide an ontology, a vision of reality in its decisive features. One would therefore expect contemporary philosophy to have taken up the challenge of technology, to have inquired into the origin and fundament of the age of applied science and engineering, and to have furnished theories of technology in the wider sense. But most such theories have come from the social sciences. The philosophy of technology is just beginning to develop as a discipline. A theory, however, needs no philosophical hallmark to be appropriate. Let us look, then, at the theories themselves to examine their adequacy. Such a survey has scholarly precedents and can benefit from them. What follows here is not intended as a survey of all surveys of theories of technology. The intention is rather to gain entry to the problem of a theory of technology by way of looking at a few summaries of such theories.

These summaries distinguish a multitude of approaches, but all distinctions fit well one of three essential types: the substantive, the instrumentalist, and the pluralist views of technology. In the substantive view technology appears as a force in its own right, one that shapes today's societies and values from the ground up and has no serious rivals.[5] Hence that view is sometimes called the "sociological approach" or "technological value determinism."[6] The explicit proponents of the substantive view usually depict technology as a pernicious force, and so their position can be labeled "antitechnologist."[7] Implicitly, however, all the writers who speak of the "imperatives of technology" are committed to the substantive position though there is much inconsistency as regards such commitments.[8]

The substantive view is theoretically inviting because of its ambition and radicality. It seeks to give a comprehensive elucidation of our world by reducing its perplexing features and changes to one force or principle. That principle, technology, serves to explain everything, but it remains itself entirely unexplained and obscure. The most important example of this approach is given by Jacques Ellul. He paints the most comprehensive and somber picture of the omnipotence of what he calls the technical phenomenon which establishes itself through various techniques.[9] But his terminology is tellingly shifting.[10] Though the technical phenomenon is initially described as something very close to the essence of modern technology and a technique is defined merely as any methodical procedure to achieve an end, *technique*, nevertheless, comes to carry the entire explanatory burden. "technique" (sometimes qualified as "modern") is invoked as the autonomous and irresistible power that enslaves everything from science to art, from labor to leisure, from economics to politics.[11] How can technique, so generally defined, accomplish this? Ellul mentions two additional factors that must enter technique or technical operations to produce the technical phenomenon, namely, consciousness and judgment.[12] These are presumably human factors. But Ellul devotes the concluding part of his book to showing that humanity has lost control over technique and is overwhelmed by it. If that inconsistency were resolved, the qualified concept of technique would still suffer from a debilitating generality. A consciously applied method may be more powerful than an implicit one, but to what ends will it be applied? For Ellul the answer is provided by the notion of efficiency.[13] But efficiency is a systematically incomplete concept. For efficiency to come into play, we need antecedently fixed goals on behalf of which values are minimized or maximized. Those goals remain in the dark. From the omnipotence of technique we can infer, however, that whatever the goals may be they cannot be forces in their own right which could give guidance to technical developments. Technique is presumably its own end, and this is what the description of the characteristics of modern technique suggests.[14] But now we have come full circle in our search for the explanatory base of Ellul's analysis. Modern technique, a power in its own right, is put forward by Ellul as its own unexplained explanation.

Talk of such an obscure and pernicious power is easily dismissed as a demonizing of technology.[15] Ellul's important and fruitful observations are then lost along with his pivotal concept. Although he had anticipated the major points of Galbraith's *The New Industrial State,*[16] Ellul's theses found little resonance because the central obscurity of Ellul's book made them so easy to ignore.[17] That ease is accommodated by the availability of a much more familiar and seemingly more perspicuous view of technology, namely, instrumentalism. There is a continuous historical thread that leads from our ensemble of machines back to simple tools and instruments. We may think of both machines and tools as affording possibilities of which we can avail ourselves for better or worse. The extension of human capacities through artifacts is as old as humankind itself. A human being is, simply, a toolmaker and a tool user. Hence the instrumentalist view of technology is sometimes called the anthropological approach. A variant of the anthropological perspective is the epistemological view.[18] Here the focus is not on the development of humans and their tools but on the methodology that modern technology embodies as a way of taking up with reality, particularly in distinction to scientific procedure.[19] If technology is at bottom a mere instrument, the inquiry of *what guides* technology becomes a task in its own right. The determination of the guiding values is sometimes held to be a matter of rational inquiry. "Rational value determinism" is therefore by implication a species of instrumentalism.[20]

The notion of technology as a value-neutral tool or instrument is congenial to that liberal democratic tradition which holds that it is the task of the state to provide means for the good life but wants to leave to private efforts the establishment and pursuit of ultimate values.[21] In that view, technology appears to have a well-defined place in public policy. Radical critics generally accept the instrumentalist view of technology but claim that it is naive at best to disregard the ends technology serves in Western democracies. Those ends are said to be the welfare of the ruling elite and the exploitation of the working class. To ignore these issues is to cast a technological veil over social reality.[22] A penetrating inquiry of technology must inevitably be a social critique. This approach, sometimes called "politicized technology," is an important kind of instrumentalism.[23] Indeed, if one is persuaded that the political dimension is decisive in human endeavors, any analysis of technology can be evaluated as to its political salience, and it becomes possible to give an array of prominent analyses from left to right.[24]

The instrumentalist approach is in one way unassailable. Any concretely delimited piece of technology can be put forward as a value-neutral tool. But it is a shortsighted view. The availability of mere means is itself a remarkable and consequential fact. Historically, it is just in modern technology that such devices become available. As I will show later, it is an equivocation to speak indifferently of tools in a modern and in a pretechnological setting. A means

in a traditional culture is never mere but always and inextricably woven into a context of ends.

If it is true that the presence of mere instruments in modern technology is consequential, then it must be misleading to continue to speak of ends and goals in a traditional manner. Putting technology in the context of political purposes is itself naive if one fails to consider trenchantly the radical transformation of all policies that technology may bring about. Indeed, Ellul and Galbraith who have been assessed and criticized within the political framework have forcefully challenged the adequacy of that framework, a challenge not always sufficiently met by their critics. The challenge, briefly, urges that traditionally radical distinctions, say, between socialism and capitalism, between union and management, have been eroded by modern technological or economic developments. Politics, then, is no longer the undisputed master science; it may well be in the thrall of a radically new and different force.

These questions will occupy us throughout this book. The present considerations suffice to show that in the instrumentalist view technology does not come fully into relief. Instrumentalism does not constitute a proper theory of technology. The failure that ambition suffers in the substantive view of technology and the obstacles that constrain common sense in the instrumentalist school of thought invite a more cautious and circumspective approach, one that takes account of the various evolving trends and complexities and of the many interacting forces. It has been called the "evolution and interaction" approach.[25] Essentially, it is a form of pluralism in that it meets all comprehensive approaches with reminders of counterexamples, unresolved problems, and disregarded evidence. The pluralist sees it all, the entire complex web of numerous countervailing forces. Against this picture any proposal of a great and consequential scheme must appear as a falsification of reality. Ironically, the pluralist view does very well with opposing theories, but it fails reality. Technology, in fact, does not take shape in a prohibitively complex way, where for any endeavor there are balancing counterendeavors so that no striking overall pattern becomes visible. It is intuitively apparent that in modern technology the face of the earth is transformed in a radically novel way; and that transformation is possible only on the basis of strong and pervasive social agreements and by way of highly disciplined and coordinated efforts. These crucial matters escape the pluralist's minute and roving scrutiny. The pluralist view is at bottom a learned reflection of the ambiguity we noted in Chapter 1.

Clearly, the theory of technology that we seek should avoid the liabilities and embody the virtues of the dominant views. It should emulate the boldness and incisiveness of the substantive version without leaving the character of technology obscure. It should reflect our common intuitions and exhibit the lucidity of the instrumentalist theory while overcoming the latter's superficiality. And it should take account of the manifold empirical evidence that

impresses the pluralist investigations and yet be able to uncover an underlying and orienting order in all that diversity. It is the purpose of the paradigmatic explanation of technology to provide such an illuminating theory of technology. To avoid misunderstanding, let me repeat that my concern is with modern technology and its character. I will at times use the appropriate qualifier as a reminder. But often, in what follows, I will simply speak of technology when I mean modern technology. Now although the actual development of a fruitful theory of technology is a difficult task and of uncertain success, the program can be clearly laid out. It is a matter of discovering a basic pattern or paradigm that has been serving us since the beginning of the modern era as a blueprint or template for the transformation of the physical and social universe. If the pattern turns out to be clear and remarkable, it can serve as the pivot of a helpful theory of technology, one that would tell us more clearly what our goal has been, to what extent we have achieved it, and where we ought to turn should our achievements appear dubious to us. Perhaps such an ambitious goal is unattainable. It will be prudent in any case to take the first steps toward it carefully and to raise from another angle the question of what should guide the choice of a theory of technology.

3 The Choice of a Theory

Is it a sufficient recommendation for the classification proposed above that it is able to subsume so many others? It is easy to devise an equally or more inclusive scheme, either by moving to a higher conceptual level or by setting up sufficiently broad categories of classification. How is one to choose among competing classifications? All of them must meet the condition of internal consistency and of applicability to their subject area. But many will pass these tests, and there cannot be a sufficient condition of adequacy; for no classifying scheme can be exhaustive in taking explicit account of all properties and relations of an area. A classification orders an area in certain regards. It highlights certain features and obscures or suppresses others. It is necessarily selective; and once one is assured that a classification is consistent and applicable, one can pursue the question of adequacy only by asking, What are the concerns that have motivated the particular selection of features that are highlighted by the present classification?

We have touched on these methodological problems in Chapter 1, and we will have to return to them again. For now I want to put the question above to the classification system developed in the preceding chapter to characterize more closely the orientation of this investigation. We will obtain a tentative answer by comparing the present classification with one developed by Carl Mitcham.[1]

His is one of the most searching and comprehensive classifications, and it has been rightly praised for its rigor, originality, and exhaustiveness.[2] It begins by distinguishing (as I did above) between the narrow sense of technology (used by engineers) and the broad sense (used by social scientists). One might use this distinction to proscribe all philosophy of technology by insisting that technology, as its clear and narrow meaning suggests, be left to the experts, the people who truly know what technology is in its mechanical, chemical, and electrical aspects. But most of Mitcham's efforts are devoted to clarifying the phenomena located toward the broader end of the spectrum that spans the meaning of technology, and he attends to the philosophical tasks that are implied in those phenomena. These efforts assume that the way in which the products of technology in the narrow sense enter the everyday world is problematic and that this problem is perhaps more troubling and important than the technical problems that are internal to engineering. Mitcham's procedure is open to a more ambitious assumption, namely, that a profound problem of technology arises not just locally at the intersection of engineering products and the everyday world but that there is a global problem of technology; technology may be thought of as a force or an approach to reality that is all-pervasive. In that view engineering is not the origin and focus of technology and its problems but merely one and perhaps the clearest manifestation of a more inclusive and decisive phenomenon. It was to make room for this radical thesis that the distinction between the substantive and the instrumental sense of technology was introduced above.

Initially, at any rate, Mitcham rejects the radical thesis by defining technology as "the human making and using of material artifacts in all forms and aspects."[3] Technology so understood contrasts according to Aristotle's distinction with "human doing—e.g., political, moral, or religious action."[4] This point, as Mitcham stresses, is important for its force regarding philosophical practice. Philosophical analysis has traditionally ignored human making, and today, too, one will look in vain for philosophical reflections on technology in most textbooks and anthologies. But it is not clear that the Aristotelian distinction corresponds to a contemporary difference. Today it may be illuminating only in the remarkable fact of its disappearance. Human making has overgrown and suffocated human doing, truly political action in particular. That, at least, is the point of Hannah Arendt's influential book on *The Human Condition*.[5]

Mitcham then distinguishes three major dimensions within the full spectrum of the meaning of technology: the subject or material, the functional or structural, and the social or historical. It is the middle one that is further analyzed, and it is best understood from its complements. The material dimension lies close to technology in its technical or engineering sense. The social and historical dimensions are entrusted to historians and social scientists. To call the remaining dimension structural or functional is, it seems to me, simply to use cautious terms for "essential."[6]

But why the concern with the essence of technology? One answer might be that knowledge of the essence of technology would allow us to gain a firm grip on technology. Yet in one sense technology is nothing but the systematic effort to get everything under control.[7] And so the pursuit of the essence of technology would result in the unchecked advancement of technology—instead of what? Again the distinction between the substantive and the instrumental sense of technology makes room for an answer. If technology is thought of as a nearly irresistible instrument, the danger arises that we embark on an endless and aimless course of problem solving. If technology is said to be a force in its own right, we may pause and consider the ways of technology. In particular we will reflect on whether technology fulfills our deepest aspirations, and such reflections in turn may lead us to ask what in the world moves and sustains us most deeply. These questions are, of course, among the essential ones of traditional philosophy, and they, I am sure, are the basis of Mitcham's concern with the essence of technology.[8]

Though the substantive notion of technology opens up these questions, it also, as noted before, closes them too quickly and simply. Mitcham forces one to be more circumspect; he points out that the function or structure of technology displays three distinct aspects: "technology-as-knowledge, technology-as-process, and technology-as-product—or thoughts, activities, and objects."[9] Mitcham rightly insists that any definition (and theory, to be sure) of technology ought to be tested in light of these essential distinctions. They reflect a traditional *ordo essendi* in that the distinctions apply well to human technology from its first beginnings; and an *ordo cognoscendi* in that most scholarship is centered on one of these aspects of technology. Thus the distinctiveness of modern technology and the particular claims of a theory of technology have an appropriate background in the terms of Mitcham's distinctions. Particularly as regards the objects of technology, it is a fair if demanding requirement that a philosophical theory of technology have something to say about the machines and products that surround us daily, and to do this in a mode that undercuts and illuminates the language of engineering and economics in which we normally speak about the technological furniture of our age. In discussing technology as process or activity, Mitcham singles out making and using as the "root distinctions."[10] Here again the traditional cast of this distinction provides an adequate focus for a crucial phenomenon in modern technological societies, the fact, i.e., that the balance of making and using has been shifted to using in the mode of consumption. Membership in that society is typically exercised through consumption. The general participation in making, on the other hand, has declined in terms of expertise and responsibility. These too are matters on which a theory of modern technology must shed light.

Regarding technology as knowledge, the inevitable task of a contemporary theory is to come to grips with the relation of modern science and technology. This is perhaps the most basic task of an investigation of technology and the one that is most often neglected or ineptly treated. Mitcham distinguishes a

fourth aspect in the structure of technology—technology as volition. Most philosophers would accept knowing, doing, and objects as phenomena or distinctions sufficiently well-grounded in the prereflective, everyday world to provide unobjectionable starting points for philosophical analysis. To be sure, people make everyday distinctions between knowing and willing as often but not as well. Many philosophers would protest this distinction from the start as being prejudicial or confused. Mitcham acknowledges the obscurity of the nature of willing.[11] And one should add that, while knowing in the general sense in which it designates the mental realm and contrasts with the realm of activity and of objects is fairly unproblematic, knowing when distinguished from willing becomes itself questionable in its outlines and boundaries. The reason why Mitcham persists with the problem of technology as volition is his insight that when the three preceding aspects of the structure of technology are attended to, there remains a troubling question about the ultimate springs and principles of technological activity.[12] In particular, he argues that attention to technology as volition can open the problem of how or indeed whether technological means do conform to our deepest aspirations, a problem that too often gets a facile treatment in terms of the selection and realization of one's values.[13] We return here to the issue that is approached from a different angle when one asks: Is technology a powerful instrument in the service of our values, a force in its own right that threatens our essential welfare, or is there perhaps no clear problem of technology at all, merely an interplay of numerous and variable tendencies?

The three parts of this question are raised and answered affirmatively by the instrumentalist, the substantive, and the pluralist schools of thought. That they cannot all be right at once is readily apparent. The more helpful lesson that we can learn from Mitcham's survey tells us that modern technology is evidently too complex and powerful a phenomenon to fit one of the answers above to the exclusion of the others. This point in turn leads us back to the task of discovering a fundamental pattern in technology that, when explicated, corrects and unites partial and, at first sight, incompatible views. One source of the inconsistency and confusion that one discovers in surveying the dominant views of technology is the lack of a principled understanding of science. Science and technology are usually named in the same breath when one tries to discern the character of our time. Science and technology are thought to be much the same or at least aspects of one and the same enterprise. This is a fatally misleading and confusing assumption as I now want to show.

4 Scientific Theory

Science is both the subject and the rival of the philosophy of technology. A theory of technology must talk about science to explain the relation between

science and technology. But it is also true that a theory of technology, in attempting to outline a world view, is in competition with science since it is science that today sets the standard of explanation and is widely thought to give the most accurate description of our world.

We accept this privileged rank of science in our dealings day in and day out. When asked to explain an illness, the phases of the moon, or the rate of inflation, we will not resort to the wrath of God, a dragon in the sky, or the vices of people. Rather we attempt to give a physiological, astronomical, or economic analysis as best we can. When a well runs dry, a horse becomes lame, or a car breaks down, we demand that action be taken on the basis of scientific information. We talk seriously about the origin and the structure of the universe in scientific terms and save stories of creation and of the sun's chariot for special occasions.

It is difficult to establish whether such reflections accord with sociological fact, and the chief difficulty is this: one cannot presuppose, either with the public or among experts, a clear and common notion of what science is. There is no general agreement whether a sharp distinction must be made between science and technology. And among those who are willing to distinguish there is much controversy about the origin and status of scientific laws and explanations.

It is possible to measure the public's command of scientific facts, and it is deplorably weak.[1] Science as a whole seems to be a prohibitively complex and confusing phenomenon to the public, and its responses depend on what facets of the phenomenon and which inclinations of the respondents come into play. Science is sometimes confused or identified with technology.[2] But if the questions are suitably framed, a distinction is made.[3] Generally people's opinion of science and scientists is high.[4] In particular people respect and trust science more the better educated and the more acquainted they are with it.[5] The vociferous critique of science as an unprincipled and dehumanizing force is clearly not shared by the public at large. Do people therefore have a scientific view of the world? One very limited study suggests that this is so where people are in command of their situation and that they resort to religion for an explanation of their predicament when resignation is all that is left.[6]

We touch here upon a problem that will require more attention. It is of the first philosophical rank and concerns the question: With what degree of insight has the normal citizen of the technological society appropriated his or her world? An answer must aim at an equilibrium of reflection and empirical research.[7] The latter is required because the intuitions that guide our reflections are at times entirely at variance with more general facts. Yet the available data are always inconclusive because opinion surveys are of necessity directed by simple and brief questions which must elicit ambiguous responses. A survey as a rule cannot invite respondents to probe, clarify, and justify their responses. If today's typical world possession is of concern, one must boldly develop one's insights as an eyewitness and member of this society. But one is also bound to test these insights as far as possible against empirical findings.[8]

The entire exercise will of course be pointless if no attempt is made to expose today's normal world citizenship to criticism, to expose its inconsistencies and liabilities, and to free and strengthen its profoundest aspirations. As a first step in this direction, let us try to remove some of the confusions that beset the common view of science by separating three senses of (modern) science. These are (1) science as a human and social enterprise, (2) science as the body of well-established laws and theories, (3) science in its applications. Of these, the second sense is central. The laws and theories of science are the goal of science as a social enterprise and the basis of its applications. Science in its central sense gives a representation of the general structure of reality that, for the first time in human history, exacts universal assent. Whereas science as a human enterprise shows all the features of other human works—ambition, ingenuity, heroic effort, resignation, treachery, jealousy, failure—science as a body of laws and theories is objective and cogent. Again, in the application of science there is resourcefulness, imperialism, generosity, wastefulness, recklessness. But none of these is attributable to or sanctioned by science in its second meaning. It makes no difference to the validity of a scientific law whether it has been discovered by a Jesuit or a Communist and whether it is applied to kill or to cure.

To argue this way is to urge a distinction between science and technology. Science in its third sense should be called technology. And science in its first sense only is essentially dependent on or allied with technology. But it is dangerous to settle matters so quickly. Do all scientific theories have an equal claim to objectivity and cogency? How precisely do they establish a standard for explaining and understanding our world as was earlier said? How does technology fit into the scientific view of the world? Is it *merely* applied science? We need more detail and illustration to answer these questions. Let us look at an example of scientific explanation.

5 Scientific Explanation

Why does grape juice turn to wine? It has long been known that through the influence of yeast the sugar in the must is converted into alcohol. How does the yeast get into the must? Some have held that it is generated spontaneously. But beginning in the eighteenth century, experiments were conducted to show that yeast does not arise from nothing, only from yeast. Yeast is already present on the grapes or in the vats and casks. From the same must, it can produce wines that differ in alcohol content, color, and taste. "Yeast" is a collective term and covers many strains, some of which aid in the making of

bread and beer. Most beloved of winegrowers is *Saccharomyces cerevisiae* var. *ellipsoideus*.[1] Like all yeasts, it consists of microorganisms as was first seen by van Leeuwenhoek in 1680 with hardly more than a good magnifying glass.[2]

How does yeast transform sugar into alcohol? Fermentation can be described by a formula, first reported by Gay-Lussac in 1810:

$$C_6 H_{12} O_6 = 2C_2 H_5OH + 2CO_2$$

One sugar molecule is converted into two alcohol and two carbon dioxide molecules.[3] But like "yeast," "sugar" and "alcohol" cover many kinds. Here we have glucose and ethanol. What role does the yeast play in this? Does the yeast bring about the transformation by rearranging the atoms in mechanical fashion? That view was put forward by Liebig in the nineteenth century.[4] Pasteur argued, however, that in fermentation the yeast ingests the sugar, releases the alcohol and carbon dioxide as waste products and retains a net gain of energy for growth.[5] It took many more decades to work out the links in the long chain of these reactions in which enzymes play a crucial role.[6]

Anyone would give an answer of this sort to the question of why must turns to wine and to the subsequent questions. We may not go so far into the history of science or into chemistry, but we would approve of the directions. No one would invoke the god Dionysus or insist on spontaneous change, that is, one that is not traceable to antecedent conditions in a lawful way. As the example shows, the drift to a scientific explanation is gradual and inescapable. More precisely, we move in the realm of scientific intelligibility from the start, and this becomes more evident as we pursue the explanation of a problem. Once we grant that yeast plays a role in fermentation, we cannot very well reject van Leeuwenhoek's invitation to look through his primitive microscope and to recognize that yeast consists of small organisms. And if Büchner succeeds in distilling a substance from yeast cells and finds that the substance alone brings about a kind of fermentation in a sugar solution, we have no good reason to withhold acceptance.[7] Then, if organic chemistry identifies that substance as a mixture of enzymes and isolates these catalysts and the reactions they make possible, this is but a further and consistent series of steps in the explanation of the change from must to wine. Finally, we might press on and explain organic chemistry in terms of physical chemistry, the latter in terms of physics, and we may end with a consideration of work at the frontier of physics, namely, in nuclear physics.

Along the explanatory route, there may be obstacles or dissent about this step or that. We have seen that this is historically so. But such controversy does not regard the direction and consistency of the explanatory course. If one accepts fermentation and yeast, one will accept cells, enzymes, chemical reactions, and so on down to our best current knowledge of subnuclear structures and processes. Such considerations amount to an argument in support

of scientific realism, the view, in other words, that the directly unobservable elements and processes of which science speaks are just as real as the tangible phenomena from which it proceeds and to which it returns.

The opponents of this standpoint, the scientific instrumentalists, are struck by the differences between the point of departure, bubbling, frothing, brownish, sweet-sour must, and the final explanatory level of nuclear physics with its abstract formulas, intangible particles, and its austere language. So they want to draw a line between the tangible reality of the everyday world and the abstract objects of scientific explanation. But where can a principled line be drawn across the explanatory continuum that encompasses both extremes?

Still, the charge of artificiality in scientific explanations seems to be supported when we remember that the explanation sketch above ignores much that comes to pass in the change from must to wine: the development of the wine's bouquet and color, the maturing of the wine, the countless nuances and features lovers of wine recognize and cherish. Scientific explanation, however, is endlessly resourceful. Any challenge that is clearly advanced can be taken up scientifically. The great majority of past challenges has been met. It is a desperate move to try to secure a transscientific solidity for the everyday world by resting one's case on clearly stated but scientifically unsolved problems. Our common understanding of the world is always—and already—scientific. More precisely, everyone takes a protoscientific view of the world. The objects around us, large and small, are seen *within the range of scientific explanation*. Regardless of one's present competence or concern, most everyone admits that scientific scrutiny of any event or phenomenon is possible in principle; nothing falls beyond the scope of the sciences. The validity and also the ambiguities of this view will become clearer when we attend to *the structure of scientific explanation*, its validity in this chapter and its scope in the next.

To say that the world is real and intelligible is to say that it is lawful. Aristotle was the first to show in a resourceful way that we always and already move within a lawfully articulated world.[8] In particular, those who assert an endlessly shifting and unreliable reality can do so only to the extent that they tacitly take their position in a stable world. Much later and under very different circumstances, Kant argued similarly that there must be necessarily binding rules of structure and coherence if our individual experiences are to have objective validity.[9] From this it follows, as both Aristotle and Kant argue, that to render something intelligible is to place it explicitly in the matrix of laws and principles.[10]

One may find by simple inspection that must has turned to wine. But that process becomes intelligible only when it is seen as an instance of the law according to which, in the presence of yeast cells, the sugar of a solution is converted into alcohol. We can put this more formally, calling the phenomenon to be explained the *explanandum* and the principles and specifications that provide the explanatory insight the *explanans*.[11]

explanans { Sugar, dissolved in water, is always converted into alcohol when yeast cells are present in the solution.
Must is a sugar solution, and yeast cells are present in must.

explanandum { Therefore must turns to wine.[12]

Or more generally:

explanans { laws
initial conditions

explanandum { event or process to be explained

And formally:

explanans { (lawlike) premises
(particular) premises

explanandum { (lawlike or particular) conclusion

This kind of explanation is called deductive-nomological since it can take the form of a syllogism where, from premises among which there is at least one empirical law (Greek *nómos*), a conclusion is deduced. The logical form a scientific explanation exhibits mirrors the cogent force of the latter. If the laws and conditions are accepted as true and the rules of logical inference are followed, then the truth of the proposition that refers to the event to be explained cannot be refused. Aristotle used the Greek word *apodéixis* as a technical term for this kind of compelling demonstration, and, when it is a matter of highlighting the cogency rather than the structure of scientific explanations, I will refer to them as apodeictic explanations.

To understand a particular event in seeing it within the framework of regularities is the common and pervasive way in which humans orient themselves in their world. To sow seeds is to act in view of the law of germination, growth, and fruition. To slaughter an animal is to proceed on one's general knowledge of the sustaining force of meat. Scientific explanation is not a novel assault on the world but the radical precisioning of a procedure that is as old as humanity. The procedures become precise through the sharpening of the laws to which phenomena are reduced. That must turns to wine is itself a rough sort of law. When we say that yeast, along with other factors, causes the fermentation, we say something more precise. But precision in one place requires precision everywhere else. The action of yeast produces alcohol. Yet the mere production of alcohol is not yet the production of wine. The development of colors and tastes is also involved; so are acids, tannins, and esters. Further, yeast cells require for their growth not only a sugar solution but also nitrogen, vitamins, minerals, and a certain range of temperature.

When we so analyze fermentation, we have already taken the standpoint of *modern* science. From that point of view, fermentation appears as a manifold and complex chemical process, and the terms "must" and "wine" designate stages that are selected for convenience, not for reasons that derive from the laws of chemistry. Indeed, "fermentation" itself has a selective function. It tells us, if we are *observers*, what to pay attention to and what to ignore when we follow the fate of the grape from the vine to the cask. What the word tells us if we are *practitioners* is a question that will later lead us to central problems in the philosophy of technology.

The seemingly opaque phenomena and processes of the everyday world become perspicuous in the matrix of scientific laws. Opacity gives way to perspicuity as the molar objects are analyzed into their microscopic components and events are subsumed under laws. The move from the molar to the microscopic is at the same time a move from diversity to sameness.[13] The laws of chemistry hold for baking bread as well as for fermentation, and for metallurgy as well as for organic processes. It is conceivable that the change from sugar to alcohol is a lawful but not further analyzable process. Any theory of explanation must end with such ultimate laws. But modern science has shown that the final structures of our world lie several stages removed from their tangible appearances.[14] Sugar is a compound, analyzable into molecules, these into elements, the latter into atoms, and those into particles and subparticles. And at one or another of these stages the lines of analysis that depart from bread or bronze converge and become one.

In part, the laws of modern science allow us to restate and explicate what we knew prescientifically. Winegrowers have always known that sunshine and well-drained soils are crucial for productive vines. Science elucidates these phenomena in terms of photosynthesis and minerals. In part, modern science corrects our prescientific views. Naively, we are inclined to overestimate the substance that is drawn from the soil since we are unaware of the carbon dioxide in the air as a raw material. Finally, modern science discloses entirely new phenomena. No one could know without science that air contains nitrogen which is in part captured by rain and so becomes a nutrient for the vine. Through such disclosures the network of relations that constitute the context of our world becomes richer and tighter. We come to see the cycle of the production of oxygen in photosynthesis and its consumption in respiration. We can follow the path of calcium from the soil to shrubs, to the antlers of a deer, to the rodents that consume the antlers. We see cycles in the course of water and in the weather; we see courses of development in geological formations.

Thus modern science gives us a more coherent and detailed view of the world. It lets us see more precisely what a phenomenon consists of, and it

connects that phenomenon more definitely and more manifoldly to other phenomena. Science reveals detail because its theories ultimately treat of microparticles. Science is in one regard a microtheory. In constituting *one* microtheory for all the varied phenomena it discloses the many bonds of commonness among phenomena. This is the explanatory power of science: it explains everything more precisely and more generally than any prior mode of explanation. From this we should conclude that science can also provide a precise and general explanation of technology just as it has furnished one for fermentation. We know as a matter of fact that this has not been done. Is it to be expected? Is it a matter of principle or of practical circumstances that a scientific explanation of technology has not been forthcoming? What is the scope of scientific explanation?

6 The Scope of Scientific Explanation

A deductive-nomological explanation makes explicit how an event fits into the lawfulness of reality. It outlines the place of an event in the nomological network. Explanation in this sense brings into relief clearly and in some cases surprisingly an understanding of the world that is implicitly present all the time. To repeat: intelligibility is of one piece with lawfulness. To say that reality is lawful is simply to highlight the solidity and steadiness of the world. We could not be at home in the world if it changed in strictly capricious ways. Unforeseen events stand out against a world that is understood in its lawfulness, and, if an event that has exploded our nomological network and taxed our understanding is at all of concern to us, we will not rest until its relation to the laws of nature is understood.[1]

Subsumption under laws, be it explicit or implicit, is surely necessary for an explanation and understanding of events. Scientific explanation is the clear and ideal case of such explanation, and Hempel and his followers contend that any kind of explaining is valid only to the extent that it approximates this ideal. Of course in many situations an approximation is all that is needed or possible. But is subsumption under scientific laws also sufficient to explain an event? Two objections have been advanced against a positive answer. The first denies the claim of necessity and sufficiency, the second the thesis of sufficiency only. In taking up these challenges we provide a clearing for the paradigmatic explanation of technology.

It has been said on behalf of historians that they usually explain the events of history without recourse to laws.[2] But it seems that, where defenders of the autonomy of historical explanation agree that a certain event is given and that we want to know why it happened, they cannot sketch a satisfactory

answer without an appeal to laws of some sort. Thus the way in which this controversy is formulated always leaves the impression that historical explanation is at bottom but a species or variant of scientific explanation, and in this context the idiosyncracy of historical and the limits of scientific explanation never come into view.

The objections that have been raised against the sufficiency of the deductive-nomological model of explanation are more fruitful. Hempel himself has noted that a scientific explanation provides an answer to an (explanation seeking) why-question but not to a request for an explanation of a thing or concrete event. There is no scientific reply to the demand: Explain the northern lights to me. But there are answers to such questions as: Why do the northern lights pulsate? Why do they show red and green colors? A why-question selects an aspect from a concrete thing or event that is sufficiently precise to be subsumable under laws.[3] But even when the explanandum has the required sentential form, it can be subsumed under very different laws because indefinitely many causal lines intersect at the place where an event is located in the nomological network, and so the event instantiates and is subsumable under many laws. There is usually a common understanding regarding the aspect of the explanandum which is of concern and should be explained. When a particular subsumption does not accord with one's understanding, one may doubt the sufficiency of the deductive-nomological model of explanation.[4] Hempel makes the point that a subsumptive explanation shows that an event was to be expected and that in this sense it "enables us to *understand why* the phenomenon occurred."[5] But it is clear that when an explanation disregards that aspect of the event that is of concern to me, it fails to satisfy my need to understand. Hence a satisfactory account of explanation must raise and answer the question of the relevance of the factors to which an explanandum is related.[6] One can try to highlight the explanatory concern by resolving the ambiguity of an explanandum through emphasis in, additions to, or redescriptions of the explanandum.[7] Say I see a hawk sitting on a fence post that I know to be four feet high.[8] The hawk seems to be looking at a squirrel on the ground, three feet from the base of the post. After the hawk and the squirrel have disappeared, a friend of mine, who also has been observing the scene, measures the distance from the top of the fence post to the spot where the squirrel sat and asks: Why was the hawk sitting five feet away from the squirrel? The question is ambiguous in at least two ways. If my friend is concerned with the geometrical relations of the situation, I will answer by subsuming the initially given distances under the Pythagorean theorem and deduce the distance from hawk to squirrel. On the other hand, if my friend is concerned to know why the hawk did not take after the squirrel, I will resort to laws of animal behavior which explain under what conditions a predator is inhibited from pursuing its prey.

Can we say that once an explanatory concern is stated unambiguously its subsumption under the relevant laws by way of special conditions is sufficient

to explain the event in question?[9] One could simply agree to define the matter in this way. But if one also agrees that explanation begets understanding and that understanding always admits of explication by explanation, then the narrow definition of explanation just contemplated leaves much of our understanding inexplicable. There are a number of gaps in our understanding of what it means to explain something, and they open up around scientific explanation itself. To begin, we must remember that a scientific explanation normally gets underway only when the scientific laws are given. Even in the case where the laws are discovered in an attempt to solve a problem, the discovery itself, though it is part of an explanation, is not thereby explained. We have no general explanation of how scientific laws are discovered. This is not for lack of attention. Historians and philosophers of science have devoted much ingenuity and diligence to the study of how new scientific laws and theories arise. But what understanding we have of these matters is not derived from deductive-nomological explanations. More particularly, rationalist or inductivist explanations of the emergence of scientific laws which at least emulate the rigor of deductive-nomological explanations have proven quite inadequate. It is worth remarking that the philosophers of science who remind the general historians that their successful explanations are of the deductive-nomological cast do not attempt to cast their own explanations of the history of science in that mold. Another gap is found on the opposite side of scientific explanations. An explanation gets underway only when it is clear what problem is worthy and in need of explanation. But again we have no general explanation of how problems get stated.[10] A closer look at the first gap will lead us to a better understanding of the second.

The problem of the rise and succession of laws and theories in the history of science has many aspects. An important thread in this history and its discussions emerges when we consider that there is apparently no rule whose application leads to progress. This appears from a study of the details and circumstances of any scientific breakthrough. The lack of a rule is equally well demonstrated by the failure of those allegedly possessing such a rule to achieve genuine and consistent progress. Scientific progress seems to be unpredictable in any strict sense, and that is to say, unexplainable.

Yet if we speak of progress in the succession of scientific discoveries, there must be a pattern in this development, and it must be one from weaker to stronger stages. These two findings are not really incompatible. Scientific advances may well be inexplicable and incomprehensible when we look at the future. The hitherto unthought is as of now unthinkable. But that is a psychological limit. Looking at the past, after a great thinker has thought through what seemed unthinkable, the advance will exhibit theoretical ties to the past that are clear to all experts.[11] Progress up to the present is theoretically and hence psychologically perspicuous. Progress in the future is psychologically veiled and hence theoretically opaque.

Thomas Kuhn whose thought on these matters has become well-known and influential has never denied that scientific research makes progress. He has certainly denied that progress is steady and by accumulation. However there is an issue on which Kuhn seems divided, and it is a truly controversial and interesting one. It regards the question of how radical the discontinuities in scientific progress are.[12] We seem to face a dilemma. On the one hand, if the periods ushered in by new scientific theories or paradigms are radically different from their predecessors, they are incomparable or incommensurable with them. We would then have change but not progress.[13] It is the immersion in the details of history that makes us hesitate to belittle and reduce the differences among eras to degrees of crudity and ignorance. One is tempted to posit not just psychological or epistemological differences but differences in the nature of reality, i.e., ontological differences.[14] On the other hand, we cannot deny that in the development of science theories supersede one another in attaining ever greater explanatory power.[15] As noted before, however, the power has not expanded to cover its own history and character.

The result of the history of scientific progress does not explain itself in the deductive-nomological sense in which we have taken "explanation" so far. But the history does exhibit a pattern which can be pointed out. Let us concentrate on one feature of this pattern and point it out very tentatively and briefly. The early scientific theories of the Western world had both world-articulating and world-explaining significance. To articulate something, i.e., to outline and highlight the crucial features of something is also a kind of explanation. It is the kind of explanation that *can* satisfy the request for an explanation of a concrete thing or event. I will call it *deictic* explanation to distinguish it from deductive-nomological or subsumptive explanation. Aristotle's theories were explanatory in both senses. His physics and astronomy contained laws that permitted deductive-nomological or subsumptive explanations.[16] But these laws were moored in the singular structure of the cosmos articulated and pointed out in Aristotle's theory or vision of the world. The articulated world order of Aristotelian physics and astronomy is more or less of one piece with the world of Aristotelian metaphysics, ethics, and all his other disciplines. In this world order, everything had its place and rank. The movements or changes of things could be predicted on the basis of laws which reflected the privileged dimensions of the world and the rank of things. The Aristotelian laws were of limited explanatory power in that each held only for a small class of phenomena (e.g., for sublunar horizontal motion), in that they yielded only rough or relative predictions, and in that they were inconsistent with one another.

The progress of science is marked by improvements in the scope, precision, and consistency of the laws. In thus gaining greater explanatory power in the deductive-nomological sense, the laws lost their power of world articulation. Einstein's theories of relativity no longer reflect or point up a singular world.

They do have deictic power in the sense of delimiting a set of possible worlds and ruling out certain impossible worlds.[17] We can observe a similar pattern in the development from alchemy by way of chemistry to nuclear physics. Alchemy reflected in its laws a definite world of a limited number of stuffs and transformative forces and processes. Nuclear physics, being a microtheory, allows for an indefinite number of molar worlds.

This pattern in the progress of science has no a priori character. It is an empirical fact that the world can be explained in the powerful scientific theories that we now have. The pace of the discoveries of these theories is a matter of historical fact. But given these two facts, it was inevitable that the deictic power of the sciences waned and all but vanished. This is not a failure of science. Nor is it the case that the *deictic* achievement of the earlier sciences was unquestionable or unique. *Art* has always been the supreme deictic discipline. Art in turn has sometimes been one with philosophy, religion, and politics; at other times these disciplines have complemented or competed with one another as disciplines of deictic explanation.

No marshaling of evidence and no elaborating of arguments are required to support the statement that the traditional deictic explanations have lost their force. Artists, prophets, and philosophers are not among the people who are consulted by government when a crisis is to be met or a course of action is to be charted. Politics itself provides the arena of today's most common and consequential discourse, to be sure; but it is less clear whether politics also sets the tone and standards for public discussions and decisions. One must at least consider the possibility that technology has robbed politics of its sovereignty and substance. If, on the other hand, laws of modern science do not by themselves bring out the crucial and remarkable features of the modern world and so fail to provide the orientation needed for political action, it appears that there is a gap of explanation and insight opening up between the apodeictic explanations of the sciences and the deictic explanations of our heritage. Perhaps this lacuna can be filled by the paradeictic or paradigmatic explanation of technology. But before I act on this possibility in Part 2, we must consider more concretely and in detail the connections between science and technology. In particular, we must take account of the contentions, contrary to the suggestion above, that the scientific enterprise in conjunction with technology or with technology as its consequence has in fact begotten a new kind of order by which we are destined to live.

7 Science and Technology

Let us begin with this framework and hypothesis for the explanation of modern technology. We may think of modern science as having rendered the world

perspicuous by setting it within the matrix of scientific laws. In this matrix it appears as one possible world. It might, within the same matrix, be differently arranged. Or in other words, any definite state or event in the world can be subsumed by way of its initial conditions under scientific laws. And any such state or event might have been prevented or modified if the conditions had been different. Thus, the change of conditions in accordance with scientific laws yields great transformative power. Modern science lets the world appear as actual in a realm of possible worlds. Modern technology reflects a determination to act transformatively on these possibilities.[1]

Neither science nor technology, however, has a theory of what is worthy and in need of explanation or transformation. Given an explanandum or transformandum, they will explain and transform the problematic phenomenon; neither has a principled way of problem *stating*. To be sure, science has authentic access to the problems that arise within a research program.[2] But these are not the problems whose solutions constitute the technological transformation of the world. Technology in its turn, merely as the determination to transform, faces an indefinite number of transformative possibilities and cannot provide principled guidance to problems.

But before we ask what guidance or pattern there is to the technological transformation of reality, we must consider the influence of modern science on modern technology, the latter tentatively defined as the typical way in which one in the modern era takes up with reality. Consider the following illustration. Wine is an ancient drink and has had an important place and rank in the human world. Like many other things, wine began to be analyzed in terms of modern science with the rise of that science, and the research of the nineteenth century led to a first culmination of this development, a sketch of which was given in Chapter 5. But research has continued, of course. Finer and finer details in the production and the composition of wine are being understood. The process from the vine to the bottle is, in light of the laws of physics and chemistry, seen as a finely detailed stream of physicochemical events. Similarly wine, the product, is visible as a complex substance of organic and inorganic chemicals. Some of the phases or features in the traditional process are laborious and time consuming, some are harmful, others inessential. And similarly with wine. Some substances in the traditional product are not palatable, some threaten its stability, others that are desirable are often in short supply. How should we act on such insight? The answer is not difficult when there is a mortal danger to the vine or a persistent problem of wine spoiling. But where should we draw the line in interfering with the traditional process and product?[3] To take an extreme possibility, once the chemical composition of traditional wine is fully understood, it becomes possible to produce a substance much like it that is not derived from grapes but in another, more efficient way. Is it just sentimentality that prohibits one from calling the new substance wine also? Is such a prohibition any more

consistent than if we refused to call something a table unless it were made of wood?

Given the very limited common knowledge of science, it is clear that there cannot be on the part of the public either an explicit knowledge of the fine structure of things or any grounded knowledge of just how these things may be technologically modified, replaced, or supplemented. It seems, however, that there is a general and implicit understanding of the scientific perspicuity and technological malleability of our world. The public takes in stride scientific breakthroughs and technological innovations because they occur within a horizon of general familiarity. We might venture to say that with all the scientific illiteracy there is a public understanding of the sciences as a principled or lawful illumination of reality which opens up new possibilities for dealing with the world. To be sure, that understanding rests on a narrow base. All of us know at least bits and pieces of science. But most of us are only peripherally in touch with the body of scientific theories and with the social organization that undergirds it. But tenuous as the connections may be, as long as there are no inconsistencies or severe disruptions, the public seems to have a sufficient warrant for its correct if vague understanding of science.

Though it is true that science in revealing the lawful fine structure of reality provides new insight and possibilities, one may easily take a second and unwarranted step by inferring that modern science has thereby ushered in a new world view. This inference is greeted by some with triumph and by others with distress. Little is known about the public view in precisely this regard, but the distinction is well worked out as regards the scholarly and literary community.[4] The pursuit of this problem allows us, at any rate, to come to a conclusion about the relation of modern science and technology.

What about the thesis that the scientific enterprise embodies a substantive way of taking up with the world, positively or negatively? Historically, the positive case can be made by showing that science was a liberating event, a breaking of the fetters of superstition, ignorance, and dogmatism.[5] These forces science replaced with rationality, honesty, and a public and inquisitive attitude.[6] A more straightforward argument holds that an inspection of the scientific enterprise reveals that the practitioners of science are held to singularly stringent and august criteria of achievement.[7] Finally, an application to the problem of technology is made when it is held that the deplorable chaos of the contemporary world results from our failure to carry the scientific enterprise to its conclusion by explaining and shaping human behavior according to the best available scientific knowledge.[8]

The first of these three arguments is the strongest because it can point to the very real clashes of scientists with traditional world views. In light of our earlier remarks on the progress of science, it must be admitted that, as the scientific theories advance, they more and more withdraw their endorsement of established world views. If a totalitarian power demands such an endorsement, withdrawal is often both undertaken and acknowledged as a revolution.

But it is one thing no longer to fulfill a task and quite another to fulfill a task in a new way. Scientific progress can at most be *liberation from;* it can never constitute or provide the thing that it is a *liberation for.*

More specifically, when scientific endorsement is withdrawn from a world view, the latter is required to abandon in light of that withdrawal those of its elements that hitherto provided or implied deductive-nomological explanations, those elements, i.e., from which, together with particular conditions, empirically testable predictions could be derived. For the withdrawal of endorsement in scientific progress is not a wanton shift of allegiance but the reflection of the discovery of new and more powerful laws and new explanations that are thereby possible. But it is a mistake to think that a world view must shrink to nothing after it has given up its scientific elements. The Aristotelian hierarchy of being need not be given up with Aristotelian mechanics and dynamics. Accordingly, Einstein's relativity theory has no counterpart or counterargument to the Aristotelian hierarchy. To be sure, withdrawal of scientific endorsement forces a world view back to its deictic resources. If these were slim or unwholesome to begin with, this will now become apparent, and the world view may collapse. Conversely, the more purely and fully a world view is by its nature articulated in a deictic manner, the less it is affected by scientific progress. That is true of poetry and art in general. The more complex world views of politics and religion, however, are required not only to expel their outdated scientific elements but also to rearticulate themselves in light of new scientific laws. Both enterprises are laborious and encourage conservatism. But it is pointless to call for a substantive controversy between science and theology as Paul Feyerabend does.[9] That call will be frustrated not necessarily by the meekness of theology but inevitably by the fact that modern science cannot embody a substantive world view of a scientifically authenticated sort.

We can leave it undecided whether the scientific enterprise as a sociological or psychological phenomenon is singularly edifying or pernicious, whether it would lead us to happiness or ruin.[10] In neither case would the guidance originate from the center of the enterprise, i.e., from the body of the established laws and theories of science. But the rise of science as a power without guidance for the world may have substantive consequences in its own right, and technology may be foremost among them. A world whose articulation disintegrates may as such display definite and consequential traits. This is roughly the thesis of Hans Jonas.[11] More particularly, he holds that modern science has not only withdrawn its support of established world views but promoted their dissolution and the establishment of an alternative vision. The world's cosmic architecture is denied and replaced by the infinite manifold of one homogeneous substrate. Manipulation and novelty are integral parts of this promotion, and it has technology as an inevitable if not immediate consequence. Technology ceaselessly transforms the world along abstract and artificial lines.

This is a considerable argument, and it can be complemented by pointing up the close sociological and disciplinary ties between science and technology.[12] It is important to consider, as Paul Durbin has done, the empirical facts and consequences of this association.[13] Still, it is possible, as Joseph Agassi and Mario Bunge have shown, to distinguish in a principled manner the scientific from the technological procedure.[14] In particular, the scientific methodology is shown to be detached from the common criteria of success as one would expect from a discipline not committed to the establishment of a particular world view.

The distinction between science and technology is also eminently desirable for a critique of technology. Jonas's thesis is so strong because he does not derive technology primarily from science as a sociological phenomenon, i.e., from the habits and characteristics of the scientific community. Rather he derives it from the core of science, from the nature of the scientific laws and theories and of the explanations they make possible. But this strength is also a weakness by is consequences. Current science at its core is true; true in the sense that its theories give us the best representation of the general structure of reality. The truth a realist claims for science can be denied from an instrumentalist position; but the latter is plausible only as long as it avoids precision. The instrumentalist cannot, as we have seen, draw a definite line between everyday knowledge which has access to supposedly real states of affairs and scientific knowledge which, it is claimed, merely deals with convenient and useful formalisms. Yet if we accept the realist view of science and admit that what our current scientific theories and explanations say of the world is true, then we must also admit that technology, if it is the necessary consequence or companion of science, is equally true. Putting it more discursively, technology on that view is a mode of taking up with the world, which is entirely and necessarily in accord with the true nature of the world. One can then deplore the truth of science and technology. But one can criticize technology only in violating the truth.

As we have seen, however, a proper appraisal of the core of science and of the methodology immediately surrounding and serving that core does not warrant an inference from science to technology. That inference does not fail a priori, but it certainly does in fact. A concise and consistent formulation of Jonas's principal thesis fails to agree with crucial features of the technological world. The thesis holds that modern science renders the world homogeneous, infinite, devoid of an encompassing structure and goal. If these processes and their results are not just necessary for technology but sufficient, then technology is nothing but the reduction of the world to unbounded, unstructured homogeneity. Any thesis can be saved by modification, and the present thesis holds if the presence and effects of technology are restricted appropriately. But it is clear from Jonas's discussion of the Industrial Revolution, of mechanics, chemistry, electricity, and electronics that he does not accept the drastic restriction of the significance of technology which the consistency of the thesis would require.[15]

But if technology harbors formative forces that cannot be delineated through recourse to modern science, how can they be delineated? Surely the modern world does not in any plain and indisputable sense tend toward greater homogeneity and loss of structure. On the contrary, where technology is most advanced, the world is most radically and tightly restructured. We can conclude then that the sciences reveal in a principled manner the general structure of reality and that the resulting insight is known to provide great transformative power. Scientific knowledge is a necessary condition of modern technology; it is not, however, sufficient. The question remains of how technology acts on the transformative possibilities provided by science, and the description of the character of technology is a task in its own right. In Part 2 we will try to discover and explicate the basic pattern of technology and determine how and with what consequences we have transformed our world according to that pattern.