Science at the Bar

Law, Science, and Technology in America

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For Maya

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Foreword

Perhaps it is no surprise that in a society as diverse as America, the law and the courts play so large a role. These institutions in effect provide the mechanisms for sorting through the competing claims and conflicting ideologies of a uniquely complicated nation. Today the legal system routinely resolves questions that literally are beyond anything that could have been imagined when the foundations of the American legal system were set in place. Still, like other public institutions created by the English colonists, the courts have proven remarkable for their resiliency and their adaptability. Indeed, it is not too much to assert that the judicial system and the law have provided the framework for the orderly adaptation of many aspects of life to modernization, political evolution, and cultural change. But nothing tests the courts' capacity for resolving disputes and setting rules more than the legal issues raised by the scientific revolution.

It is not necessary to go back to the framers of the Constitution to locate a gulf in imagination and understanding concerning the explosion in scientific knowledge. The questions science puts before us today are well beyond the comprehension of most of us. We live, for the first time in the history of mankind, in a world in which the great mass of people have no idea how their ordinary possessions—everyday items such as televisions and computers—actually work. And we live in a time when the issues raised by science, whether in the form of the genetic revolution or electronic eavesdropping, are likely to become even more intertwined with basic decisions about how we live.

Both scientists and attorneys begin with hypotheses. But interaction between the worlds of law and science in the courtrooms makes clear that they represent two very different traditions. Clashes are already common between the truth-seeking world of science and the justice-serving institutions of the law; they are likely to intensify in the future. Each field, perhaps, sees the other as easy prey for the ancient intellectual trap once expressed as "an error is the more dangerous the more truth it contains."

At the heart of the problem, of course, are the rapid technological and scientific advances that make it ever more difficult for those involved in the judicial system and for the citizens who serve on juries to understand the complex information presented by expert witnesses. Cases involving litigation over risk and evidence, such as DNA test results, are ripe with the potential for misunderstanding and confusion. The issues raised by such cases often go beyond legal procedures and the scientific method. Moreover, both legal professionals and scientists are part of dynamic social institutions that are touched by and touch upon other fields; the "facts" by which they are guided seem, at least to lay people, to be changing all the time.

In the pages that follow, Sheila Jasanoff provides a broad and insightful examination of many of the issues raised by judicial activity in this area—an area she describes as "situated at the intersection of law, science, politics, and public policy." It may well be that today much of what most Americans learn about science comes from the coverage of science in our courtrooms. The risks from secondhand smoke and microwave technology are elucidated in each case involving damages from these products; genetic research is a little clearer for us every time there is a case involving paternity; and medical advances are explained in every case involving malpractice or the right to life. That information becomes part of our knowledge base as we choose sides in political controversies involving these issues. It helps inform the debates over environmental issues wherein calculations of risk from new technologies are measured against their effects on our nation's drive for economic and technological growth.

When Jasanoff first came to the Twentieth Century Fund

with this project, she was at the beginning of a career that has helped shape a new field of study. Since then she has established the first major interdisciplinary university department of science and technology studies at Cornell University. In this book she examines the issues that we will face as the world becomes ever more complex and suggests ways for preparing to meet that complexity, such as educating those involved in the legal system or establishing alternatives to litigation. We are grateful to Jasanoff for an informed and provocative tour of these difficult issues.

Richard C. Leone, President
The Twentieth Century Fund
June 1995

Preface

This book is the product of a long and still unfinished journey. My purpose is to explore how two of the most powerful institutions in America, science and the courts, interact with each other in the face of technological innovation and political change. Scholarly interest in this relationship is of relatively recent origin, although it is growing, as evidenced by the proliferation of journals and programs of law, science, and technology in law schools around the country. For the rest of the social sciences, however, what takes place in engagements between the truth-seeking agencies of science and the justice-serving institutions of the law remains a largely unexamined problem. As a result, outside the pages of specialist journals there are as yet no canonical approaches to writing about science and technology in the legal process. If, as I propose here, our society is increasingly defining itself through conflicts that are at once scientific, technological, and legal, then the academic voices that could interpret or give coherence to these multiple, loosely connected acts of self-definition are striking by their absence.

Commentators on law, science, and technology have focused most often on the difficulties faced by judges and juries in recognizing "good science" and "legitimate expertise," both of which are presumed to exist unproblematically in a world that is independent of the day-to-day workings of the law. Such writing takes for granted the capacity of scientists to settle factual disputes and to distinguish legitimate from illegitimate claims without on the whole being swayed by external influences. Science, in this reckoning, is not in itself a questionable source

of authority; the problem, if any, lodges in the legal system's inability to recognize the proper emissaries of science and defer to the messages they carry. This view of science as an autonomous and largely self-regulating field of inquiry is often joined to a view of the law that conceives of scientific validity as a precondition for rendering justice. From this perspective, it is easy to reduce the law's obligation in relation to science to a simple, two-step prescription: courts or other legal institutions should first seek out the findings of mainstream science and then incorporate them into their adjudicatory decisions.

The approach I take here assumes to the contrary that scientific claims, especially those that are implicated in legal controversies, are highly contested, contingent on particular localized circumstances, and freighted with buried presumptions about the social world in which they are deployed. The institutional setting of the law shapes the representation of legally relevant scientific claims at many points, beginning with the articulation of standards for what counts as valid science within the legal process. In other words, ideas of truth and ideas of justice are co-constructed in the context of legal proceedings. Legal controversies over "good science" and how to find it accordingly serve for me as starting points for a more discursive inquiry. I wish to understand how the legal process mediates among conflicting knowledge claims, divergent underlying values, and competing views of expertise in a democratic society.

The law plays an equally fundamental role in constructing the fit between technological artifacts and their social context. Advances in the realm that is conventionally labeled "technological" inevitably require the readjustment of existing human behaviors, institutions, and relationships. They enable new modes of conduct—and sometimes foreclose old ones—thereby calling into question notions of fundamental significance to the law, such as agency, causality, rights, responsibility, and blame. The redefinition of concepts such as these around new scientific and technological developments, and the underlying successes and failures of judicial skill and imagination, are among the central concerns of this book.

My account of the law's interactions with science and technology has been influenced by a deepening commitment to the

field of science and technology studies over the past ten years. Work in this field calls attention to the negotiable boundaries of many things whose hardness we ordinarily take for granted, such as facts, institutions, social roles, and even inanimate objects. A core project of science and technology studies has been to display the fluidity of the divisions among the social, material, and natural worlds, showing that much of what we know through science or use as technology is produced and given solidity through socially accredited systems of rhetoric and practice. Science, in particular, emerges from this analysis not as an independent, self-regulating producer of truths about the natural world, but as a dynamic social institution, fully engaged with other mechanisms for creating social and epistemological order in modern societies. Within this analytic framework, the interplay of law and science acquires particular significance, since the law's power to articulate social norms becomes tightly interwoven with science's efforts to declare unchanging truths about the nature of our physical world and our own selves. Seen close up, legal disputes around scientific "facts" often appear as sites where society is busily constructing its ideas about what constitutes legitimate knowledge, who is entitled to speak for nature, and how much deference science should command in relation to other modes of knowing.

The questions I grapple with in the following pages are situated at the intersection of law, science, politics, and public policy. The idea of "social construction," which is central to current scholarship in science and technology studies, provides a conceptual connection among chapters dealing with topics as varied as expert witnesses, judicial review, toxic torts, and the regulation of new technologies. In each context, legal proceedings function as a medium for constructing and stabilizing particular orderings of science and technology in society. At the level of legal analysis, I am particularly interested in the formal and informal techniques by which courts legitimate some, and exclude other, possible interpretations of technical expertise, claims, products, and processes. From legal scholarship, as well as from science studies, I draw my concern for the ways in which general claims and principles emerge from

the particularities of specific cases and controversies. The book's political dimension derives from the fact that constructions of science and technology in the legal system invariably redraw the lines of power and authority, as when the law opens up new areas of technical decisionmaking to review or control by nonexpert publics. One of the book's major conclusions arises from its mix of disciplinary perspectives: the legal system, I argue, has been instrumental in creating and sustaining public understandings of science and technology in the very processes of "using science" to resolve technical controversies. It follows that one cannot fully comprehend the place of science and technology in American political life without closely attending to their deployment in the legal process.

My thoughts about this book have benefited enormously from conversations with many friends, colleagues, and students in science and technology studies. I am especially grateful to Dorothy Nelkin, whose early and enthusiastic encouragement led me to this field. Michael Dennis, Evelleen Richards, Wesley Shrum, Laurence Trancredi, and Brian Wynne all provided much-needed incentives to carry on with the project when self-doubt and other pressures threatened to overwhelm it. Many colleagues in the realms of law and science contributed with valuable information and still more valuable reality checks. My contacts, both formal and informal, with the American Association for the Advancement of Science and the American Bar Association through the National Conference of Lawyers and Scientists were particularly helpful in expanding my awareness of the issues faced by practicing judges, lawyers, and expert witnesses in technically complex cases. I owe a special debt to Bert Black, Joseph Cecil, and Edward Gerjuoy for their unfailingly thoughtful and informative collegiality, and to Mark Frankel, Deborah Runkle, and Albert Teich for drawing me into many stimulating interactions through AAAS. Thomas Gieryn, Michael Reich, Joseph Sanders, Peter Schuck, and several anonymous reviewers provided exceptionally perceptive and generous readings of the penultimate draft of the manuscript.

Work on the book was supported by the Twentieth Century Fund at a time when external recognition was especially important to a struggling academic in a then little-known interdisciplinary research program. I am deeply grateful for this support and for the continued, near-saintly patience of Beverly Goldberg and her colleagues Pamela Gilfond and Roger Kimball, through the protracted recasting and revision that followed the award. My assistant Deborah Van Galder was as always a source of efficiency and strength, as were my research assistants Nora Demleitner at Yale Law School and Lauren Gelman, Jennifer Huang, Olive Lee, Tania Simoncelli, and Robert Speel at Cornell. I am also indebted to Robert Gulack for thoughtful critical comments on an early draft. Most of all, I thank the members of my family who bore with the book and its author through many tribulations—my mother, Kamala Sen; my husband, Jay; my son, Alan; and, not least, my daughter, Maya, whose life has unfolded in tandem with my life in the law.

Although the book has been enriched by the help and insights of many people, choices of content and interpretive strategy have been mine alone. Thus, I have not attempted to be comprehensive in my descriptions of contemporary legal encounters with science and technology; many important topics, such as intellectual property law or psychiatric, medical, and social science evidence, receive only passing attention in the following pages. Instead, this book represents an initial attempt to open up what I hope will be a continuing and mutually enriching conversation between science and technology studies and the law. I see it not as a final resting place but as a temporary vantage point from which to survey the surrounding terrain more clearly and from which others may be inspired to climb further and reveal new heights. The book will serve its purpose very well if it makes even a few of its readers look with reawakened interest at the changing configurations of science, technology, and the legal order in our vibrantly litigious society.

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The Intersections of Science and Law

American political culture derives its distinctive flavor as much from faith in scientific and technological progress as from a commitment—some might even say an addiction—to resolving social conflicts through law. These powerful cultural predilections have brought the institutions of science and technology into turbulent confrontations with the legal system, raising doubts whether the nation's intense concern for health, safety, environmental protection, and traditional moral values can be reconciled with its yearning for sustained economic growth and an endless technological frontier. Disenchanted with legal approaches to problem-solving, influential critics in universities, industry, and government have called upon the law to adopt a more deferential or hands-off attitude toward science and technology. The legal system is again being urged to leave the resolution of scientific disputes to scientists, and even the much-maligned idea of a "science court" has enjoyed a minor renaissance.

How should policymakers—lawyers, politicians, scientists, and informed citizens alike—come to terms with this groundswell of discontent? Does the fault, if any, lie exclusively with the courts in the often controversial encounters between law and science? Or do our own expectations concerning science and technology need to be modulated in the light of what we know about the limits of adjudication and the nature

of scientific inquiry? I address these questions by looking more closely at what actually takes place in legal disputes involving science and technology. How do the distinctive actors, institutions, procedures, and formal languages of the law shape the meanings that science and technology acquire in people's everyday lives? How are public understandings of science and technology altered or, alternatively, exploited when legal resources are brought to bear on the resolution of technical controversies? And how does litigation constrain or redefine our collective ability to control the development of technology? In exploring a variety of techno-scientific disputes in the legal arena, I will reexamine many of the received opinions underlying scholarly writing on law and science and will consider the benefits of a more reflective, self-aware response to science and technology by the legal system.

America's preoccupation with progress through science and technology appears, at one level, to be solidly grounded in historical achievements. A century of inventions has enlarged our capabilities and improved our quality of life in myriad unpredictable ways. At every turn we encounter new material indicators of progress: air bags and antilock brakes, electronic mail, fax machines and bank cards, heart transplants and laser surgery, genetic screening, *in vitro* fertilization, and a burgeoning pharmacopeia for treating mental and physical illness. In just one generation the space program has expanded the physical frontiers of human experience, while discoveries in the biological sciences have revolutionized our ability to manipulate the basic processes of life so as to fight infertility, aging, hunger, and disease. Scientific research continues to attract generous public funding, even in a time of political skepticism and budget deficits. Although some "big science" projects, such as the Strategic Defense Initiative (SDI, or "Star Wars") and the superconducting supercollider, lost their appeal with the end of the Cold War, others, such as the space station and the project to map the human genome, continued to attract governmental support despite vigorous criticism from the political and scientific communities.

Increasing knowledge, however, has also reinforced some archetypal fears about science and technology that overshadow

the promises of healing, regeneration, material well-being, and unbroken progress.[1] Rachel Carson's *Silent Spring*[2] achieved global bestsellerdom in the 1960s with warnings of a future in which animals sicken, vegetation withers, and, as in Keats's desolate landscape, no birds sing. Genetic engineering, rightly seen as one of the great scientific breakthroughs of this age, has been etched on the public consciousness as the technique by which some modern Dr. Frankenstein may fatally tamper with the balance of nature or destroy forever the meaning of human dignity. Communication technologies speed up the process of globalization but threaten to dissolve the fragile ties that bind individuals to their local communities. The mushroom cloud, nuclear winter, the "hole" in the stratospheric ozone layer, the "greenhouse effect"—these disturbing images all suggest that our civilization's Faustian thirst for knowledge has outstripped our capacity to foresee and ward off the effects of dominating nature too completely.

Opinion polls and the popular media reflect the duality of public expectations concerning science and technology. A 1992 Harris poll showed that 50 percent or more of Americans considered only science and medicine to be occupations of "very great prestige," but that these ratings had fallen by 9 and 11 percentage points, respectively, since 1977.[3] According to another survey, the proportion of people expressing a great deal of confidence in scientific institutions remained fairly steady, at 36–45 percent, between 1973 and 1993. Yet in 1993 more than 45 percent of the public felt that there would be a nuclear power plant accident and significant environmental deterioration in the next twenty-five years; slightly smaller percentages expected to see a cure for cancer and a rise in average life expectancy in the same period.[4] Ambivalence prevailed in Europe as well. In polls conducted in 1989, more than 75 percent of respondents believed that science improves the quality of life and should be supported by the state, but 28–65 percent disagreed or disagreed strongly that scientists could be trusted to make the right decisions.[5] Following the unprecedented success of the film *Jurassic Park* in 1993, a science reporter for the *New York Times* observed that, at least in the eyes of the popular media, "drug companies, geneticists and other

medical scientists—wonder-workers of yesteryear—[were] now the villains."[6]

Much of the recent entanglement of law and science reflects the American public's determination to bring under control the darker side of technological mastery: risks to public health and the environment, to individual autonomy and privacy, and to community and moral values. From Tocqueville to the present, commentators on American culture have called attention to this country's particular penchant for resolving political controversies and achieving social order through law. It is hardly surprising that in an age of anxiety about the products of science and technology the U.S. public has increasingly turned to law to reassert control over the processes of scientific and technological change or to seek recompense for the failed promises of technology.

Yet, as we near the end of the century, law no less than science has lost much of its progressive mystique. Litigation today is perceived more as a cause of than a cure for some profound malaises of American life. The soaring costs of legal proceedings, combined with attacks by political conservatives on judicial activism, have reduced the credibility of the courts; an excess of law is blamed for many of the problems that have beset U.S. science and technology in the recent past, from plummeting medical school applications in the 1980s (a trend since reversed) to corporate bankruptcies, delays in product introductions, and lagging industrial competitiveness. Prominent social critics, including not only scientists but also members of the bench and bar, argue that the power of the courts must be checked if the United States is to be pulled out of a downward economic spiral.[7] In their tactically brilliant, ten-point "Contract with America" of September 1994, the Republican Party promised a Common Sense Legal Reform Act that would introduce "loser pays" laws, limit punitive damages, and reform products liability laws so as to discourage litigation. The erosion of faith in legal processes and institutions reflected in these developments is as much a part of the context for this book as is the public's often expressed distrust of technical experts and their undemocratic authority.

Truth or Justice?

Complaints about the legal system's handling of problems related to science and technology correspond in general terms to two distinct yet well-established traditions of science policy analysis: one concerned with "science in policy" and the other with "policy for science."[8] While one can question the basis for this binary distinction, it continues to dominate public perceptions about the mismatch between the needs of science and technology and those of the legal process.

The project of "science in policy" has encompassed repeated proposals to "improve" the use of science in legal decisionmaking by reforming the selection of expert witnesses, reeducating judges and juries, and changing the standards for validating technical evidence. Critics often note that American judges, juries, and lawyers know on average very little about the social organization and processes of science, still less about basic scientific concepts such as "statistical significance," and almost nothing about the substantive content of particular scientific fields. Yet these "technically illiterate" fact-finders, who understand neither the substance nor the methods of science, are increasingly called upon to discriminate among sophisticated technical arguments. Lacking adequately trained gatekeepers, the legal system allows itself, in the view of some critics, to be swamped by "junk science," while truth and rationality fall victim to the manipulative dynamics of the adversary process.[9] Cross-examination and the legal rules of evidence operate only as recipes for obfuscation, while the control of expert witnesses by litigants brings to court only the most extreme and unrepresentative opinions about the technical issues at stake in litigation.

Daniel Koshland, an editor at *Science*, one of the nation's premier journals for the biomedical sciences, occasionally used his position to direct satirical barbs against the legal system. In the following extract, a naive "Science" learns the facts of legal life from "Dr. Noitall":

> *Science.* So the judicial system is not a system to get at the truth as simply as possible.

Noitall. Finally you understand. The judicial system is an adversarial system in which clever lawyers match wits with one another. If a lawyer defending a mobster murderer can show a technical discrepancy that gets his client free, the lawyer is widely admired even though a killer has been freed.[10]

Though written by a scientist for the consumption of other scientists, such storytelling nevertheless exemplifies a significant form of boundary maintenance between science and the law. On the pages of *Science*, "science" emerges as unswervingly committed to the truth, while the law is shown as intent on winning adversarial games at any cost.

The critical project concerned with "policies for science" has focused mainly on the inefficiencies of judicial decisionmaking as an instrument for managing technology. Observers in this camp question whether the judiciary is institutionally capable or constitutionally empowered to make policy on issues such as biotechnology, nuclear power, or new medical and reproductive technologies. Because of jurisdictional constraints, neither the state courts nor the lower federal courts seem qualified to develop policy on a national scale. Moreover, the retrospective and case-by-case methods of adjudication seem to many to be fundamentally incompatible with the nation's need for forward-looking responses to science and technology. The impact of the courts on innovation, liability, the selection and funding of substantive research programs, and the regulation of technological risk appears from this standpoint to be a significant obstacle to progress.

Both of these standard framings converge in their assumption that science and, to a lesser extent, technology possess an inner logic, an autonomous framework of validation and control, that operates irrespective of the law and does not need to be subjected to the law's normative concerns or institutional practices. Prescriptions for injecting "good science" into legal decisions—for example, by delegating scientific issues to scientists or making legal actors more technically literate—are a manifestation of our society's deep commitment to a rational, and hence reliably objective, policy process. Those who would lower the legal barriers to scientific creativity and technological innovation are similarly wedded to the idea that technology

policy is best handled by expert, rational decisionmakers. Each of these conceptualizations attributes, in my view, an untenable firmness to the boundary between science and technology on the one hand and law and policy on the other. Recommendations for institutional separation, such as the formation of science courts, along with demands for better science in the legal process, chronically overestimate the power of experts to rationalize moral and political choices about science and technology.

The Cultures of Legal and Scientific Inquiry

The contrasts between law and science are often described in binary terms: science seeks truth, while the law does justice; science is descriptive, but law is prescriptive; science emphasizes progress, whereas the law emphasizes process.[11] These simplified characterizations restate in varying ways the insight that fact-finding in the law is always contingent on a particular vision of (and mechanism for) delivering social justice. Scientific claims, by contrast, are thought to lack such contingency. Although its conclusions may be speculative, provisional, and subject to modification, science is ordinarily seen as set apart from all other social activities by virtue of its institutionalized procedures for overcoming particularity and context dependence and its capacity for generating claims of universal validity. Not surprisingly, then, comparisons between science and the law often celebrate science's unique commitment to systematic testing of observations and its willingness to submit its conclusions to critical probing and falsification.[12]

The representation of law and science as fundamentally different enterprises has given rise to two strikingly recurrent themes in legal writing about science: that of the "culture clash" between lawyers (or legally trained bureaucrats) and scientists, and the corollary that the culture of law should strive as far as possible to assimilate itself to the culture of science when dealing with scientific issues. Cultural disparities are offered to explain the discomfort that scientists feel when asked to express their technical judgments in the heavy-

handed categories used by regulators, or when they are cross-examined by lawyers who dredge up minor inconsistencies to impugn the experts' credibility.[13] Analysts of the law, it appears, feel almost as uncomfortable about these confrontations as the scientists they describe. Prescriptions for overcoming the alleged cultural conflicts between law and science range from injunctions to the courts to borrow the standards scientists themselves use in distinguishing "real science from . . . pale imitations"[14] to suggestions for professional mediators, such as science bureaucrats or science counselors, who will enable each culture better to understand the other.[15]

Missing from this literature is any but the most cursory attention to the commitments and practices that actually constitute the culture of science. Still less effort has been dedicated to understanding the scientific subcultures that have coalesced in and around the processes of adjudication. In the following chapters I will use insights from science and technology studies, supplemented by case studies of particular areas of legal development, to challenge the abstract and idealized view of science expounded by most proponents of the "culture clash." Taking real decisions and controversies rather than wishful scenarios as the point of departure, I will argue that the cultures of law and science are in fact mutually constitutive in ways that have previously escaped systematic analysis. Understanding how these institutions *jointly* produce our social and scientific knowledge, and our relationships with technological objects, is indispensable to any effective attempt at policy reform.

As formal systems of inquiry, law and science have several important features in common. Each tradition claims an authoritative capacity to sift evidence and derive rational and persuasive conclusions from it. The reliability of observers (or witnesses) and the credibility of their observations are of critical concern to both legal and scientific decisionmaking. Unlike organized religion, neither science nor law owes allegiance to a single dogmatic authority. In both fields, rules governing the assessment of facts occasionally undergo massive shifts—in science through the work of paradigm-transforming pioneers[16] and in the law (ordinarily but not always) through the actions

of legislatures. Normal progress within each discipline occurs through a decentralized, silent revolution brought about by individuals making decisions at the frontiers of established doctrine in accordance with their personal understanding of the existing tradition.[17]

The considerable differences between scientific and legal thinking are most apparent in their approaches to fact-finding. Science, as conventionally understood, is primarily concerned with getting the facts "right"—at least to the extent permitted by the existing research paradigm or tradition. The law also seeks to establish facts correctly, but only as an adjunct to its transcendent objective of settling disputes fairly and efficiently. This basic dichotomy accounts for a number of secondary contrasts. Because the law needs closure, the process of legal fact-finding is always bounded in time: inquiry has to stop when the evidence is exhausted. The judicial inquirer cannot postpone a decision by choosing to wait for more evidence. As John Ziman, British physicist and sociologist of science, has noted, "If we are forced to a premature opinion on a scientific question, we are bound to give the Scottish verdict *Not Proven*, or say that the jury have disagreed, and a new trial is needed."[18] The law, by contrast, must take a position based on the facts at hand, however premature such a decision may appear in the eyes of scientists.

Fact-finding in law proceeds through a form of ritualized courtroom discourse that subjects the scientist's firsthand reporting of observation and experiment to additional conceptual and rhetorical filters. What the legal fact-finder "knows" is a function of what the witnesses in a proceeding choose to relate in court in answer to questions posed by lawyers. British mystery writer R. Austin Freeman wryly commented on this highly restricted form of knowing in a 1911 novel: "The scientific outlook is radically different from the legal. The man of science relies on his own knowledge and observation and judgment, and disregards testimony . . . A court of law must decide according to the evidence which is before it; and that evidence is of the nature of sworn testimony. If a witness is prepared to swear that black is white and no evidence to the contrary is offered, the evidence before the Court is that black is white,

and the Court must decide accordingly."[19] Freeman satirized, but around a kernel of truth. "Science," for the law's purposes, is simply the composite of testimony presented in and around an adjudicatory proceeding, and its quality depends heavily on the skill and intentions of the lawyers who elicit the presentation. The facts that the law constructs (or reconstructs) are thus necessarily different from the facts that scientists construct to persuade their peers in their own rhetorically and procedurally distinctive surroundings.

To serve its need for decisive endings, the law has devised a complex system of rules and practices for choosing what to believe when facts are uncertain; these rules and practices by definition are not "scientific." They include, to start with, the rules by which the legal system determines what evidence and which witnesses are relevant to the dispute at hand.[20] Another body of legal rules addresses the problem of making decisions on the basis of conflicting evidence. For example, in civil cases the legal system places the "burden of proof" on the plaintiff. In order to prevail the plaintiff must prove his claim by a "preponderance of the evidence"—in other words, more than 50 percent of the evidence must be in the plaintiff's favor. This requirement is a way of ensuring that even in those borderline cases in which the evidence is perfectly balanced the legal fact-finder will have an orderly basis for deciding between the disputants. Science under the same circumstances would be neither willing nor able to declare a winner. Administrative decisions generally call for a lower standard of proof, whereas criminal trials demand something closer to scientific certainty ("beyond reasonable doubt"). A contrafactual or contrascientific conclusion can, in appropriate circumstances, be declared the "right" conclusion from the standpoint of the law. In criminal proceedings, for instance, evidence deemed highly relevant to a scientifically "correct" determination of guilt or innocence might be excluded in order to protect individuals against coercion by the state, thereby producing a technically "incorrect" but morally just outcome.

Even in civil cases, the legal system's allegiance to values other than those of science may open the way to decisions that look like sheer irrationality. For example, in a 1946 paternity case against Charlie Chaplin, a jury held the actor liable, and the court ordered him to pay child support, even though blood-group evidence showed he could not have been the father.[21] Francisco Ayala, a distinguished biologist, and Bert Black, an engineer-lawyer, cite this as a bizarre decision that flies in the face of scientific knowledge.[22] Michael Saks, a social psychologist and expert on evidence, takes a more moderate stance, pointing out that "the jury may have doubted the manner in which the blood test was carried out, the underlying science, or the honesty of the expert witnesses."[23] Equally, Saks notes, the jury's sense of justice could have affected the outcome. Biological relationships, after all, do not always control in determining an adult's financial or custodial responsibility for a child. To ensure support for children, state laws have traditionally presumed that a child born to a married woman is her husband's legitimate offspring. Perhaps the jury analogized Chaplin's position to that of the canonical husband, taking into account his vastly superior economic standing in comparison with the child's mother. Under any of these readings, the jury's refusal to accept the scientific denial of Chaplin's paternity could properly be characterized as social wisdom rather than scientific illiteracy.

Adjudication and Technology Assessment

The emphasis on legal fact-finding in recent discussions of law and science has tended to obscure the role of courts in managing technology, although in the long run this role is arguably more important to the evolution of modern industrial democracies. Scholarly writing on the intersection of our legal and technological cultures has ascribed to courts a largely reactive role; that is, courts are seen mainly as instruments for remedying the negative impacts of technology. Conventional institutional analysis supports this view. Courts, after all, cannot initiate action on their own but must await complaints from aggrieved parties. Unlike legislation, adjudication proceeds case by case and retrospectively—that is, after harm has oc-

curred. The timing of litigation thus precludes courts in theory from the primary goal of technology assessment: "rational choice at the earliest possible stage of events."[24] Yet, as we shall see, U.S. courts are often the first social institutions to give public voice and meaning to formerly inaudible struggles between human communities and their technological creations. Technological trajectories are therefore importantly steered by events within the legal system.

Legal thinking about technology and the courts has been informed for the most part by an unexamined technological determinism. Thus, in a recent study of law and culture even so perceptive an interpreter of the American legal order as Lawrence Friedman accords little attention (only 10 pages in 206 pages of text) to the relationship between technological and legal change, and he describes the impacts of technology only in the conventionally deterministic language of cause and effect.[25] The effects include, in his telling, a heightened pace of change, an explosion of legal forms and structures, and an increase in expressive individualism, manifested in American society's growing sense of legal entitlement.

Others who also see the law as concerned primarily with technology's impacts have charged that the legal process allows its concern for individual justice to override larger societal interests, such as the industrywide or cross-sectoral effects of new liability rules. Peter Huber, one of the most outspoken critics of U.S. tort law, argues that the regulatory force of litigation systematically and disproportionately penalizes "public risks"[26] and gives preference to larger "old" risks over smaller "new" ones.[27] Huber includes in the category of public risks large power plants, mass-produced vaccines, and jumbo jets—all technologies which in his view have lowered the risks of disease and death from older, "cottage industry" alternatives such as wood stoves, automobiles, and exposure to naturally occurring toxins. Huber believes that adjudicatory decisions consistently disfavor threats to health and safety that are centralized, mass-produced, and lie outside the risk bearer's individual control. By overcompensating the victims of new technologies and discouraging their proliferation, courts increase the total probability of harm to humans and the environment.

Huber evidently presumes that people prefer those technologies that most reduce the number of accidents and that courts should simply respect these preferences. But study after study of risk perception has pointed out, to the contrary, that the public is often more concerned about the social and cultural dimensions of risk than about actual or predicted numerical impacts. Thus, people will tolerate a higher probability of death or injury from activities that they feel they can meaningfully control (smoking, eating, automobile driving) than from activities that heighten their sense of powerlessness or distrust (nuclear power, pesticide use, air transportation).[28] Doing justice in a democratic society requires courts to respect such entrenched normative positions even if they cut against the managerial preferences of the nation's scientific and technological elite.

Courts, however, bring distinctive institutional limitations as well as competencies to their construction of the relationship between material objects and social needs, and both characteristics should be addressed in a fair evaluation of their performance. Products liability litigation may produce socially insupportable dislocations when a single "bellwether" decision exerts effects far beyond the factual content in which it arises. Claims against vaccine manufacturers in the 1980s created an uncertain legal environment in which drug companies considered it more prudent to cease production than face the prospect of huge damage claims by a small number of plaintiffs.[29] The insurance industry's reluctance to assume responsibility for extraordinary damages magnified the dampening effect of tort litigation, in some cases beyond acceptable limits. In 1986, for example, several thousand patients suffering from a rare neuromuscular disorder were deprived for many months of a beneficial experimental drug because its producer could not obtain products liability coverage.[30] Congress in the same year enacted a vaccine compensation bill to transfer such claims out of the courts and put a cap on awards for pain, suffering, or death;[31] the Republican "Contract" mentioned earlier promised to generalize damage caps to areas other than vaccine compensation.

The political legitimacy of courts is equally vulnerable to

challenge when judges have to second-guess expert administrative agencies. In the early years of biotechnology development, for example, environmental activists successfully delayed the commercialization of some genetically engineered products through legal action. By deciding in favor of the environmentalists in a few such cases, courts legitimated public opposition to the executive branch's policy of promoting a technology deemed essential for the nation's competitiveness. Although public interest groups applauded these initiatives, others questioned the validity of judicial intervention in such a specialized and economically vital area of science and technology policy. Their argument (critically appraised in Chapter 7) rested in part on a narrow interpretation of the courts' policymaking function and in part on the view that courts threatened science by giving equal time to scientifically groundless fears and objections.

The notorious cost and inefficiency of the judicial process also prompt concern about the role of courts in shaping technology policy. Legal redress for technological accidents is neither cheap nor speedy. In complex cases, the expense of producing evidence and hiring expert witnesses adds significantly to the already heavy burden of attorneys' fees and court costs. A lawsuit involving claims of pollution-related disease can easily consume millions of dollars and numbers of years, especially if it proceeds to trial. One of the longest jury trials in the nation's history arose from a suit against Monsanto by residents of Missouri who claimed to have been injured by dioxin.[32] Three years of inconclusive testimony in that case convinced many participants that the legal system was helpless against abuses by determined and well-financed litigants. In 1990 the nation's longest-running criminal trial, a California child molestation case, ended without a conviction when jurors decided that they could not extract a clear interpretation of the facts from 60,000 pages of testimony by 124 witnesses.[33]

Financing complex litigation, moreover, demands ad hoc arrangements that create problems of inequity and unequal access. In a toxic tort case in Woburn, Massachusetts, the citizen plaintiffs were able to pursue their claims against one defendant, W. R. Grace, mainly because another firm had previously settled out of court for $1 million.[34] Peter Schuck's illuminating account of the massive lawsuit brought by Vietnam veterans against manufacturers of Agent Orange shows that the investments made by the lawyers, in time and money, completely overshadowed the ill-defined, uncertain, and circumscribed claims of individual plaintiffs. The Agent Orange litigation slowly evolved into what Schuck terms "a lawyers' case," with the veterans' interest in compensation and retribution taking second place to the lawyers' financial and professional interests; a similar issue seemed sure to present itself in a massive class-action lawsuit filed by a consortium of close to sixty law firms against the tobacco industry.[35] The tort system, as well, is one of the world's most costly and inefficient mechanisms for returning compensation to plaintiffs. A well-known study of asbestos lawsuits by the Rand Institute of Civil Justice suggested that toxic tort liability entailed exceptionally high transaction costs. From the early 1970s to 1982, every $1 paid to asbestos plaintiffs as compensation entailed an additional $1.71 in litigation expenses by plaintiffs, defendants, and their insurers.[36] In other words, only 37 percent of the total expenditures were recovered by the victims. Other studies have further substantiated this finding.[37]

Science and Technology in Court

To probe more deeply the engagements between science, technology; and the legal system, we need a working map of present-day litigation patterns in this area. Liability actions remain central to any map, since no serious technological mishap can occur in the United States without triggering a legal response.[38] Products liability litigation is by now so commonplace that it scarcely attracts attention unless the plaintiffs are particularly vulnerable or numerous, the defendant's conduct is especially egregious, or the monetary stakes are exceptionally large. Yet the very pervasiveness of products liability creates room for contradictory moral and political interpretations. For some, the liability action is the only device by which impersonal, profit-mad corporations can be held accountable to their exploited and economically disadvantaged victims. In this

spirit, Marc Galanter, an authority on the American tort system, celebrates its evolution through the twentieth century into a mechanism for delivering high accountability as well as high remedies to injured citizens.[39] Cases that support his reading include in recent years suits against Ford Motor Company and General Motors by victims of gas tank explosions, against Manville Corporation by asbestos workers, and against A. H. Robbins by women injured by the Dalkon Shield. Others, more critical, see products liability simply as a convenient causal framework within which people can rationalize their often unspeakable misfortunes by building tenuous connections to improbable technological causes. Claims that have attracted this charge include lawsuits by alleged victims of exposure to dioxin, breast implants, and electromagnetic fields (EMFs) from power lines. Widely publicized because of their complexity and tragic origins, these cases reinforce the image of the United States as a forum where scientific standards of proof are routinely flouted and where irresponsible juries destroy productive industries through ignorant, ill-considered verdicts.

But courtroom activity surrounding science and technology now encompasses a web of social adjustments extending far beyond liability. The rapidly growing roster of technology-related disputes challenges any simple characterization of the role courts play in mediating the fit between science, technology, and society. As the following examples suggest, the law today not only interprets the social impacts of science and technology but also constructs the very environment in which science and technology come to have meaning, utility, and force. These cases begin to alert us to the subtle connections that exist between conflicts over knowledge, the traditional preserve of science, and conflicts over responsibility, the classic preserve of the judiciary.

- A 1993 decision by New York State's highest court held that a claimant could seek damages for a drop in property value caused by public fear of a right-of-way for a high-voltage power line. The claimant was not required to prove that there were medically or scientifically reasonable grounds for the phobia concerning the effects of electromagnetic fields. The court felt that the economic question of the loss in market value could be resolved without being "magnified and escalated by a whole new battery of electromagnetic power engineers, scientists or medical experts."[40]
- In 1993 the U.S. Supreme Court overturned a seventy-year-old federal rule governing the admissibility of expert testimony and announced, in *Daubert v. Merrell Dow Pharmaceuticals, Inc.*,[41] new criteria by which judges ought to distinguish between valid and invalid scientific evidence. Among the many issues affected by *Daubert* was a line of cases challenging the admissibility of the so-called horizontal gaze nystagmus test administered by police officers around the country to drivers suspected of intoxication. The objective of the test is to correlate a visual inspection of the suspect's eyeball movements with a measure of intoxication. A California court allowed the testimony but observed that the officer offering it was not a scientist because he "drew his generalization from experience, not from experimentation, and did not attempt to quantify the relationship he observed."[42]
- A 1994 article by two prominent scientists in the prestigious British journal *Nature* declared that all scientific controversy over the technique known as "DNA fingerprinting" could henceforth be laid to rest.[43] The attempt by two formerly battling experts to create a consensus around this important forensic technique was widely seen as a response to the notorious murder trial of O. J. Simpson, the football hero and media personality who had recently been charged with killing his ex-wife Nicole Brown Simpson and her friend Ronald Goldman.
- A federal district court held in March 1993 that President Clinton's Task Force on National Health Care Reform should be viewed as an advisory committee subject to the open meetings requirements of the Federal Advisory Committee Act. Although most of the task force members were federal employees, it was chaired by First Lady Hillary Rodham Clinton, who was not an officer or employee of the federal government. In support of its decision, the court cited the public's right to know what information was being given to the task force, by whom, and at what cost.[44]
- Two scientists working for the National Institutes of Health developed a computerized "plagiarism detector" to measure the degree of overlap among texts in lawsuits over copyright violations. Their zeal to perfect such a technique reflected the legal system's increasing involvement with scientific misconduct in the late 1980s.[45]

• The California Supreme Court in 1993 denied a plea by a dead man's two adult children to order the destruction of sperm that he had bequeathed to the woman he had lived with before he committed suicide. Reflecting the same changing social norms about reproduction, parenthood, and family, a Florida woman who had been married only two weeks at the time her husband died in 1994 announced that she hoped to start a family using sperm collected shortly after his death. Also in 1994, a gay man was granted visitation rights to a child he had "fathered" by donating sperm to a lesbian couple. And in Louisiana, a child born to a widow through artificial insemination a year after her husband's death was declared illegitimate.[46]

• Identification of the AIDS (acquired immune deficiency syndrome) virus, the development of a blood test, attempts to characterize and contain the risk of infection, and efforts to manufacture a vaccine produced unprecedented legal controversies. In Needham, Massachusetts, an AIDS victim employed by the New England Telephone Company filed a $1.75 million lawsuit charging that the company had discriminated against him on the basis of a handicap, breached his privacy, and coerced him not to return to work.[47] A settlement permitting the plaintiff to return to work led to a protest walkout by fellow technicians who remained convinced that his presence posed serious risks to their safety. On the international scene, France's prestigious Pasteur Institute sued the U.S. National Institutes of Health (NIH) to establish credit for the discovery of the AIDS virus and to claim a share in royalties from patented blood tests for the disease.[48] The controversy temporarily subsided when the French and American heads of state agreed that scientific credit should be shared, but it resurfaced as U.S. investigators sought to determine whether the NIH "co-discoverers" had been guilty of misconduct.[49]

• Developing technologies for extending or preserving the life of the human fetus gave rise to a bizarre series of lawsuits. A judge in Connecticut ordered that the fetus of a woman who had been comatose for nearly three months should not be aborted, because there was "insufficient evidence" to justify such action.[50] In San Diego, California, criminal charges were brought against a woman who had allegedly failed to take proper medical care of her unborn child, in contravention of her doctor's recommendations.[51] According to a hospital autopsy report, the infant died as a result of "fetal distress syndrome caused by maternal drug abuse." Although the charges were eventually dropped, the case achieved notoriety as the first attempt to use criminal sanctions for a woman's treatment of a fetus during pregnancy. And in suburban Virginia, a federal court ordered a hospital to continue providing life-sustaining treatment to a baby born with most of her brain missing. At the time of the decision, Baby K had already been kept alive for many months longer than most anencephalic babies because of her mother's insistence that she be offered mechanical breathing support during respiratory crises.[52]

Many of these cases can be interpreted as struggles over the authority of knowledge. Whose knowledge should count as valid science, according to what criteria, and as applied by whom? When should lay understandings of phenomena take precedence over expert claims to superior knowledge? Should experts' views about risk and cost structure social relationships (as in the AIDS cases), or should they give way to countervailing nonexpert values (as in the EMF and Baby K cases)? These cases also underscore the extent to which the very production of scientific knowledge and techniques is bound up with developments in the law, from police officers' tests for drunk driving to specialist scientists' efforts to define plagiarism or DNA fingerprinting for forensic purposes. More generally, this assortment of cases also reflects the unpredictable ways in which scientific and technological developments slice into settled social relationships and compel a redefinition, through law, of established rights and duties. In addressing these issues, courts in effect are enlisted into an interactive process of social and technological change; they become partners in society's search for new rules to interpret and restructure an altered array of potentialities.

Guiding Concerns

Accepting the inevitability of judicial rulemaking is not equivalent to approving uncritically the whole of the law's current edifice for resolving disputes with a high technical content. Recognition that science is socially constructed in courtroom settings does not obviate the need for judges to decide in specific cases whose evidence should be admitted or how it should be weighted by the jury. More generally, persistent critical commentary on the courts compels us to reconsider to

what extent the social adjustments around science and technology should appropriately be delegated to judicial resolution.

As our understanding of law-science interactions becomes more complex, so necessarily does the task of normative analysis. Prescriptive solutions aimed at maintaining the status quo or at enlarging the dominion of "good science" are difficult to support if one adopts the more dynamic and constructivist analysis of law and science that I am proposing. If we accept the notion that law and science are involved in constructing each other in our society, then where can we turn for criteria that will allow us to assess and improve the interactions between these institutions?

A promising approach is to turn to the courts themselves and look again at the functions that they, as distinctive institutional actors, can best perform in a democratic society of increasing technological complexity. One important task is the *deconstruction* of expert authority. Litigation, as we shall see, is an especially potent resource for making transparent the values, biases, and social assumptions that are embedded in many expert claims about physical and natural phenomena. Exposing these underlying subjective preconceptions is fully as important in a justice system as "getting the facts right." As we review a range of judicial decisions, we will therefore consider how successfully they reveal, and hence empower social criticism of, the possibly unconscious biases of expert witnesses. Courts may play a usefully deconstructive role in relation to technology, as well, by exposing "interpretive flexibility" in the meanings that technology has for different social actors,[53] and by pointing toward new possibilities for social control. It will also be important to ask whether and to what extent the judiciary's own biases concerning science and technology enter into the adjudicatory process, and whether these in turn are available for deconstruction. More generally, we will assess whether litigation is a reliable and effective procedure for disentangling the ethical and social concerns raised by advances in science and technology.

A second and related function that may reasonably be expected from the courts is *civic education* about science and technology. How effectively do courts inform litigants and

other citizens, the legal community, and various governmental and nongovernmental institutions about the epistemological, social, and moral dilemmas accompanying technological change? In this connection, it will be especially important to ask how legal fact-finders think about scientific uncertainty and controversy, and how effectively they rationalize their own decisions in the face of conflicts in the evidence. We will also be concerned with the relationship between the judiciary's analysis of science and the overall clarity and consistency of judicial rulemaking. In a similar vein, we will consider the appropriateness of legal framings chosen in relation to particular developments in science and technology (for example, the choice between a strict or a flexible construction of a statute or the choice between preserving or overruling a constitutional standard).

Third and by no means least significant is the criterion of *effectiveness*. When citizens seek redress from the courts, they expect a decision exhibiting certain practical as well as moral attributes. American litigants, in particular, are widely known to bring some quite general expectations to the adjudicatory process. Justice should not only be done but be seen to be done. Litigants should feel they actively had their day in court. Decisions should compensate people for pain, psychic distress, and outrage as well as for pecuniary loss. Compensation should not be indefinitely postponed. An effective legal system has to address these demands on a fairly regular basis. One should also ask, under the heading of effectiveness, how judicial decisionmaking combats threats to individual liberty and security, as well as how litigation influences broader national goals such as innovation and competitiveness.

The methods I use in approaching these issues are based to some extent on traditional legal analysis. Leading cases are reviewed in each chapter both because they represent innovative moments in the law and because they exert the widest influence on public understanding and behavior. But many of the questions addressed in this book, such as judicial boundary-drawing and ideas of expertise, are better illuminated by minor decisions clustering around particular areas of controversy, for example, genetic engineering or toxic torts. Most of

the following chapters are therefore organized around specific substantive topics and may be seen in a sense as extended case studies; each one combines the analysis of case law with insights from the secondary literature on the social and political context of litigation. This approach permits a more historical as well as comparative examination of the strategies that the legal system uses in constructing science and technology. Indeed, much of the analysis in the following chapters is not particularly time-bound, although wherever possible I have included striking examples from contemporary legal decisionmaking. The book, finally, is about judicial styles of reasoning and thought as they both influence and are influenced by science and technology; it does not pretend to provide the last word on any particular area of substantive law.

Chapters 2–5 focus mainly on science and Chapters 6–9 mainly on technology, although the dividing line between the two areas is not absolutely clear-cut. The construction of science within the legal system, both as a social institution and as a system of accredited beliefs, forms the subject of the next four chapters. Here, the major themes are the law's constructive as well as deconstructive treatment of scientific authority and credibility. Chapter 2 surveys the evolution of judicial attitudes in three areas of substantive law: products liability, medical malpractice, and environmental law. Historically, decisions in each of these areas responded to changing public expectations concerning the safety and accountability of technological enterprises; in the process, the courts struck new balances between lay and expert understandings of risk, benefit, safety, and harm. This progression must be understood and critically evaluated as a prelude to discussing more recent controversies involving science and technology.

Chapters 3–5 trace the influence of judicial decisionmaking on the definitions of good science, legitimate expertise, and technical rationality. Informed by perspectives from the sociology of science, Chapter 3 focuses on the recurrent epistemological and institutional conflicts around the use of expert witnesses in the courtroom and the methods that the law has devised for dealing with these problems. The chapter illuminates the multiple contingencies, both cognitive and social,

that shape scientific fact-finding in the legal system. Chapter 4 looks at the impact of the courts on the federal regulation of health and environmental hazards, with particular attention to the law's role in making governmental agencies accountable to the public for their technical decisions. Chapter 5 further develops the theme of accountability, this time with regard to relations between scientists and the public. Specifically, the chapter surveys the actions of courts in conflicts arising from scientific and medical research and the confrontation between scientific and religious values.

Chapters 6–9 are concerned primarily with the capacity of the courts to sort out controversies concerning the ethical, social, and cultural implications of technological change. Chapter 6 examines the continuing struggles about valid knowledge and appropriate standards of proof in the context of toxic tort litigation, an area of law that has proved as resistant to judicial rulemaking as to orderly legislation. Chapter 7 evaluates the role of the courts in shaping national policies for biotechnology, underscoring the judiciary's own adherence to prevailing views of technological progress. Chapters 8 and 9 review and contrast judicial performance in two areas of biomedical decisionmaking that have produced a spate of ethical dilemmas in recent years: the use of new reproductive technologies and life-sustaining technologies ("right-to-die" cases). Explanations are sought for the courts' apparently more successful ventures in the latter than the former cases, particularly along the dimensions of civic education and effectiveness. Finally, using the criteria outlined above, Chapter 10 reevaluates the dominant legal approaches to managing science and technology and presents some proposals for reforming a complex yet endlessly fascinating domain of legal practice.

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Notes

1. The Intersections of Science and Law

1. For a masterly account of the myths and images that shaped the U.S. public's attitudes toward nuclear weapons and nuclear energy, see Spencer Weart, *Nuclear Fear* (Cambridge, Mass.: Harvard University Press, 1988).

2. Rachel Carson, *Silent Spring* (Boston: Houghton Mifflin, 1962).

3. Humphrey Taylor, "Scientists, Doctors, and Teachers the Most Prestigious Occupations—But Doctors' and Lawyers' Prestige Falls Steeply," Harris Poll, June 7, 1992, in *American Public Opinion Data* (Louisville, Ky.: Opinion Research Service 1992), microfiche HAR, 7 June.

4. National Science Board (NSB), "Science and Technology: Public Attitudes and Public Understanding," in NSB, ed., *Science and Engineering Indicators—1993* (Washington, D.C.: U.S. Government Printing Office, 1993), pp. 204, 483.

5. Richard Topf, "Science, Public Policy, and the Authoritativeness of the Governmental Process," in Anthony Barker and Guy Peters, eds., *Expert Advice* (Pittsburgh: University of Pittsburgh Press, 1993), pp. 105–109.

6. Gina Kolata, "Forget the Butler; the Medical Industry Did It," *New York Times*, October 17, 1993, p. E3.

7. For an overview of these complaints, together with a reasoned rebuttal to some of the charges, see Marc Galanter, "Predators and Parasites: Lawyer-Bashing and Civil Justice," *Georgia Law Review* 28 (1994), 633–681.

8. Robert Gilpin and Christopher Wright, eds., *Scientists and National Policy-Making* (New York: Columbia University Press, 1964), p. 76.

9. The term "junk science" was popularized by Peter Huber, a lawyer and engineer, whose vivid though unscholarly indictment of the courts focuses primarily on their inability to discriminate between

marginal and mainstream science. See Huber, *Galileo's Revenge: Junk Science in the Courtroom* (New York: Basic Books, 1991).

10. Daniel E. Koshland, "Scientific Evidence in Court," *Science* 266 (1994), 1787.

11. See, for example, Steven Goldberg, "The Reluctant Embrace: Law and Science in America," *Georgetown Law Journal* 75 (1987), 1345.

12. Francisco J. Ayala and Bert Black, "Science and the Courts," *American Scientist* 81 (1993), 230–239; Peter H. Schuck, "Multi-Culturalism Redux: Science, Law, and Politics," *Yale Law and Policy Review* 11 (1993), 14–21.

13. For a sampling of the literature on the "culture clash" of law and science, see Philip M. Boffey, "Scientists and Bureaucrats: A Clash of Cultures on FDA Advisory Panel," *Science* 199 (1976), 1244–46; Leslie Roberts, "Science in Court: A Culture Clash," *Science* 257 (1992), 732–736; Steven Goldberg, *Culture Clash* (New York: New York University Press, 1994); and Schuck, "Multi-Culturalism Redux."

14. Ayala and Black, "Science and the Courts," p. 239.

15. Schuck, "Multi-Culturalism Redux," pp. 43–44; Goldberg, *Culture Clash*, pp. 103–108.

16. The classic work on paradigm changes in science is Thomas S. Kuhn, *The Structure of Scientific Revolutions* (Chicago: Chicago University Press, 1962).

17. Michael Polanyi, *Science, Faith and Society* (Oxford: Oxford University Press, 1946), pp. 45–46. Polanyi refers to law and science as regimes of "General Authority" because, in contrast to a regime of "Specific Authority" such as the Catholic church, these two disciplines decentralize the power to interpret rules. There is no official center to which individual discretionary decisions must be subjugated.

18. John Ziman, *Public Knowledge: An Essay concerning the Social Dimension of Science* (Cambridge: Cambridge University Press, 1968), pp. 14–15.

19. R. Austin Freeman, *The Eye of Osiris* (1911; reprint, New York: Carroll and Graf, 1986), pp. 123–124.

20. It has been suggested that one important difference between evidence in science and in the legal system is that in the latter "the information itself does not bear obvious credentials of its reliability and relevance." Accordingly, the law has designed "a highly developed 'law of evidence' for the presentation and testing of information offered as evidence in court cases." Jerome R. Ravetz, *Scientific Knowledge and Its Social Problems* (Oxford: Oxford University Press, 1971), p. 121. Recent work in the sociology of scientific knowledge questions whether claims based on experimental observations do in fact bear "obvious credentials" of reliability. See, for instance, H. M. Collins, *Changing Order* (London: Sage, 1985). For the purposes of this book, the important point is not whether legal evidence is less obviously reliable than most scientific evidence, but rather whether the "law of evidence" is consistent with scientific criteria for assessing reliability.

21. Berry v. Chaplin, 74 Cal.2d 652 (1946).

22. Ayala and Black, "Science and the Courts," p. 230.

23. Michael J. Saks, "Accuracy v. Advocacy: Expert Testimony before the Bench," *Technology Review*, 90 (1987), 48.

24. Philip L. Bereano, "Courts as Institutions for Assessing Technology," in William A. Thomas, ed., *Scientists in the Legal System: Tolerated Meddlers or Essential Contributors?* (Ann Arbor: Ann Arbor Science, 1974), p. 85.

25. Lawrence M. Friedman, *The Republic of Choice: Law, Authority, and Culture* (Cambridge, Mass.: Harvard University Press, 1990).

26. Peter Huber, "Safety and the Second Best: The Hazards of Public Risk Management in the Courts," *Columbia Law Review* 85 (1985), 277–337.

27. Peter Huber, "Exorcists vs. Gatekeepers in Risk Regulation," *Regulation*, November/December 1983, pp. 23–32.

28. For a sampling of this literature, see Baruch Fischhoff et al., *Acceptable Risk* (Cambridge: Cambridge University Press, 1981); Mary Douglas and Aaron Wildavsky, *Risk and Culture* (Berkeley: University of California Press, 1982); Branden B. Johnson and Vincent Covello, *The Social and Cultural Construction of Risk* (Dordrecht: Reidel, 1987); Deborah G. Mayo and Rachelle D. Hollander, eds., *Acceptable Evidence: Science and Values in Risk Management* (New York: Oxford University Press, 1991).

29. Edmund W. Kitch, "The Vaccine Dilemma," *Issues in Science and Technology* 2 (1986), 108–121.

30. Philip M. Boffey, "Drug Shipments to Resume to Treat Rare Disorder," *New York Times*, November 6, 1986, p. B20.

31. Barbara J. Culliton, "Omnibus Health Bill: Vaccines, Drug Exports, Physician Peer Review," *Science* 234 (1986), 1313.

32. Patricia B. Gray, "Endless Trial," *Wall Street Journal*, January 13, 1987, p. 1.

33. Seth Mydans, "For Jurors, Facts Could Not Be Sifted from Fantasies," *New York Times*, January 19, 1990, p. A18.

34. Matthew L. Wald, "Jury in Cancer Death Suit Says Factory Polluted Wells," *New York Times*, July 29, 1986, p. A8.

35. Peter H. Schuck, *Agent Orange on Trial* (Cambridge, Mass.: Harvard University Press, 1986), pp. 263–265; Glenn Collins, "A To-