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INTRODUCTION

Science and technology are increasingly the subject of legislative and policy decisions. These topics are frequently attended by considerable disagreement and public debate. Often, the opinions and recommendations of scientific experts contrast vividly with the opinions of many Americans, leaving policy makers with no clear consensus on how to proceed. What are the appropriate limits of scientific testimony in the formation of public policy? How are decisions regarding scientific issues to be justly made and what considerations must be taken into account when evaluating the opinions and information provided by scientific experts? The utility of scientific testimony depends critically on the nature of the decision at hand and is limited both by the culture of science and the personality traits of scientists.

I. MAKING PRUDENTIAL AND MORAL JUDGMENTS

Society has developed a collection of habits, customs, and norms that assist us in making prudential and moral judgments when confronted with new experiences and situations. Prudential judgments are concerned with practical assessments of risk and benefit: What are the most fitting means to achieve a desirable end. "Absolute power corrupts absolutely" is an example of a prudential judgment that has led to the constitutional Separation of Powers.[1] In contrast, moral judgments are concerned with the nature of right and wrong; what should and should not be done

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1. *See, e.g.*, THE FEDERALIST NO. 47 (James Madison). "The accumulation of all powers, legislative, executive, and judiciary, in the same hands, whether of one, a few, or many, and whether hereditary, self-appointed, or elective, may justly be pronounced the very definition of tyranny. *Were the federal Constitution, therefore, really chargeable with the accumulation of power, or with a mixture of powers, having a dangerous tendency to such an accumulation, no further arguments would be necessary to inspire a universal reprobation of the system.*" *Id.* (emphasis added).

in a fair and just society. "Thou shalt not kill" is an example of a moral prohibition deeply ingrained in our culture that has led to the legal prohibition of murder.

In both prudential and moral matters, we have certain cultural "guideposts" that assist in evaluating new situations as they arise. If someone proposes doing away with the legislative branch of government, we instinctively know that this is an imprudent course of action based on past experience. If we witness one man shoot another on the street, we can rather quickly determine that one man has killed another and, furthermore, if the shooting was not in self defense, that this killing is homicide.[2] In both cases, we have clear cultural and personal experiences that assist us in determining the proper course of action.

But judgment based on past experience has its limits. As long as the new objects or experiences under consideration are commonplace or readily derived from commonplace things, cultural habits are more often than not reliable guides. Pilgrims were able to grow corn, a completely new crop, because corn is sufficiently similar to other cultivated plants and the pilgrims had a long experience with cultivation. Little Johnny knows that if he takes Billy's new toy he is stealing because the toy, novel though it may be, clearly belongs to Billy. But as objects become further and further removed from common experience, they also become further and further removed from the common wisdom that is culture. Because modern science is in the business of discovering new things, it is constantly uncovering items that defy our cultural coping mechanism.

II. The Scientific Frontier

Scientific technology can draw into the realm of the possible that which had previously existed only in the world of the imagination. The doors that open at the leading edge of the scientific frontier are in many ways unlike those that are opened by other types of human expansion into unexplored domains. The newly discovered American continent held unexpected terrain for those pioneers intrepid enough to venture into the unknown, but surviving such an expedition was largely a matter of good old-fashioned common sense and ingenuity. Despite the romance and danger of an unexplored continent, the challenges presented by such a frontier are well within the historic experi-

2. *See* Black's Law Dictionary 577 (1st ed. 1891) (defining homicide as "[t]he killing of any human creature" and "justifiable homicide" as that which is committed "under such circumstances of necessity or duty as render the act proper, and relieve the party from the shadow of blame").

ence of the human race. Similarly, the forefronts of other human pursuits—art, literature, and music—are all characterized more by the novelty of their arrangements than by the uniqueness of their content. Not so with the forefront of the scientific endeavor.

The uniqueness of the scientific frontier is not due to the arcane nature of science or the inherent complexity of scientific information, but rather to the unnaturalness of the landscape opened up by scientific findings. A scientific advance that enables radically different human experiences (human cloning as a form of reproduction, for example) is not merely a new example of a familiar category, and our prior experience with "classical" reproduction offers very little to guide our response. Advances on the scientific frontier define a terrain we must navigate largely without the benefit of a historic precedent. This aspect of scientific frontier generates grave difficulties for lawmakers when attempting to set public policy. Traditionally, precedent plays a prominent role in our law as well as our own decision-making: X is similar to Y, and hence the rule that governs Y should also govern X. But when the X in question is so completely unlike anything that has come before it, when there is no clearly discernable Y to compare it against, how should one proceed?

Nowhere is the radically new nature of the scientific frontier more evident than in the field of modern molecular biology and medicine. Advances over the last decade have been profound, and the pace of discovery mind-numbing. We have seen the unraveling of the human genetic code, the ability to alter or replace genetic information at will, to generate hybrid organisms that express characteristics of two (or more) distinct species, to identify dozens of human genes responsible for disease (a process that once took decades, if possible at all), even the development of technologies to exactly duplicate entire individuals by cloning—all within the last decade. Much that once existed only in the realm of the imagination is now securely within the domain of the newly possible—a domain that is (in the opinion of many) advancing rapidly towards the previously unthinkable.

The rapid pace of advancement raises very real moral and prudential questions. Although modern biology has done nothing to undermine the prohibition against murder, it has brought to light the question of when (and where) we become "alive" and when we become "dead." Since much of what science discovers is so completely removed from previous experiences, how are sound moral and prudential judgments to be made? Given that prudence demands that dangerous technologies be controlled and decency demands that evil technologies be prohibited, we are left with the question of exactly when a technology becomes dangerous or evil.

This problem of good judgment is further compounded in the field of biology because of the intimate nature of the subject matter. Perhaps due to our inherent narcissism and self-interest, research into what makes our bodies function or fail is far more compelling and carries a much more immediate emotional impact than research into physics or chemistry. Biological research has probed topics as intimate to our human experience as our emotions, mental illness, the myriad ways in which we die, and the expanding number of ways in which we can be born. The boundaries of life and death have more than once been redefined by modern medical research, and no other field raises issues as profound or as critical to our self-conception, our values, and our very lives.

III. How to Navigate the Scientific Frontier?

Any successful navigation of the uncharted waters of modern medical research will require us first to determine whether the question is principally one of prudence or one of morals. Both moral and prudential questions are serious and carry grave consequences. In matters of science and technology, both moral and prudential issues unquestionably require input from scientists familiar with the "new realities." However, the character of the debate differs depending on whether the question is a moral or prudential one, and the authority of the scientist *qua scientist* differs vastly as well.

A question of prudence is principally a question of risk: What are the risks and what level of risk should society accept? For example, in the 1970s, the advent of recombinant DNA technology and the attendant fears of "frankenfoods" being released into the environment spurred a sustained public debate and the formation of a Recombinant DNA Advisory Committee at the National Institutes of Health. While a question of practical policy can always lead to a question of morals, in this example the debate was principally one of the risks associated with such food and how best to manage that risk.[3] There was ultimately little moral impact on the policy.

On the other end of the spectrum, there is the "debate" over in vitro fertilization (IVF) technology, which has proceeded smoothly to product marketing with nary a ripple of serious pub-

3. Sheldon Krimsky, Genetic Alchemy: The Social History of the Recombinant DNA Controversy 113–25, 181–96 (1982).

lic alarm. The pace of IVF research has been rapid—driven by strong motivation of infertile couples to have a child—despite the fact that there are serious moral questions about the technology that have yet to be resolved. Recently, concern over surrogate mothers, egg donation, human cloning, and the prospect of conducting scientific research on "left-over embryos," has indeed caused the level of public alarm to rise.[4] Many question the wisdom of the initial development of IVF technology in light of where these procedures have led us. Surprisingly, these directions were readily apparent quite early on,[5] and yet IVF technology passed silently under the radar of public alarm.

Surely the importance and emotional impact of advances in molecular medicine warrant a thorough public and legislative debate of new technologies. While such debates do not ensure a tranquil public acceptance of any and all possible developments pursuant to a new scientific finding, they are likely to maximize the probability of this desirable outcome. Input from scientists will necessarily form a critical component of this debate, and yet the nature and extent of this input must be informed by a clear understanding of the limitations of science as a discipline and of scientists as practitioners of this discipline.

IV. The Appropriate Limits of Scientific Testimony

What is the appropriate role of scientific testimony in the debate over whether and how the frontier of science will be expanded? This role will clearly differ, depending upon whether the question is principally one of morality or one of prudence and risk management. When it comes to morals, the key insight to remember is that scientific research is about the possible, not about the ethical or the good. As such, scientific evidence can inform society whether something *can,* at this point in time, be done and scientific judgment can predict whether it is *probable* something will be done in the future, but science is inherently silent on the topic of whether it *should* be done. In other words, a scientist, *qua scientist* is no better equipped to weigh-in on the moral implications of some new technology by virtue of his scientific training than is any other person. Indeed, scientists are, in many respects, uniquely *unsuited* to make moral Judgments—precisely due to their focus on the possible. Much that is "possible,"

4. *See* Avery Dulles et al., *The Gospel of Life: A Symposium,* 56 FIRST THINGS 32–38 (1995); *see also* TERESA IGLESIAS, IVF AND JUSTICE: MORAL, SOCIAL, AND LEGAL ISSUES RELATED TO HUMAN IN VITRO FERTILISATION (1991).

5. *See* LEON R. KASS, TOWARD A MORE NATURAL SCIENCE 43–127 (1985).

and a legitimate topic of investigation from the perspective of science, is nonetheless objectively evil.

In matters both practical and moral, it is nearly impossible to navigate the arcane world of the newly possible without some input from scientists themselves. Rationally considering the direction public policy will take to best serve the interests of a free and democratic society requires an assessment of what is, in fact, possible now, what will be (to the best of our knowledge) likely in the future and what risks are associated with this possibility. Such an assessment can only be made by relying on the testimony of scientific experts.

Evaluating scientific testimony and assigning it appropriate weight in the public debate requires some consideration of at least three factors that significantly limit the utility of such testimony: 1) how the culture of science and the personality selected by the profession act to bias the opinions of scientists on scientific topics; 2) how the roles of scientists as practitioners and businessmen compromise "expert testimony"; 3) how scientists are viewed by society and how popular myths and misperceptions color purportedly "neutral" scientific testimony.

V. The Culture of Science

Much has been written (often in glowing terms by scientists themselves) about the culture of science and the personality traits of the idealized scientist.[6] Far less openly acknowledged have been the ways in which science selects personality traits and behavioral strategies that limit the utility of scientific testimony in a broader social context. In particular, scientists are prone to significant blind spots when it comes to the broader interests of society—a myopia that must be taken into consideration when assigning weight to the testimony and opinions of scientific experts.

A. *Optimism Untainted by the Facts*

Scientists are fundamentally optimists. The first step in the pursuit of a scientific question is the formation of a hypothesis, based both upon the existing evidence as well as on gut-level intuition. Testing a hypothesis generally requires a considerable

6. *See generally, e.g.*, Edward O. Wilson, Consilience: The Unity of Knowledge (1998); Richard Dawkins, The Blind Watchmaker: Why the Evidence of Evolution Reveals a Universe Without Design (1996); Jacques Monod, Chance and Necessity: An Essay on the Natural Philosophy of Modern Biology (Austryn Wainhouse trans., 1972).

investment in effort and time[7]—an investment that is sustained by the optimistic hope for a positive outcome. Vindication of a scientific hypothesis is a pleasure that is hard to describe to a non-scientist: part elation over uncovering an answer; part relief that, despite the daily irrationalities of life, the universe is indeed intelligible; part triumph over odds that invariably favor a negative outcome; part just plain pride. Scientific optimism is not simply a matter of trust in the explanatory power of science, it is hope for an answer and faith in the underlying intelligibility of nature as well.

As optimists, scientists are prone to exaggerate the "promise" of scientific approaches. Rarely do scientists hold unfounded opinions (at least on scientific matters) but until *proven* by evidence, even the most well-founded scientific hypothesis remains merely an educated guess. Faith in the ultimate vindication of a particular hypothesis is not a scientific judgment; it is a matter of personal opinion. The tendency to conflate opinion (or hope) with the scientific evidence upon which that hopeful opinion is based is certainly understandable, yet it is nonetheless misleading. This conflation requires that assertions of scientists about facts not yet proven be taken with a considerable grain of salt.

Exacerbating the general tendency in science towards optimism is the fact that scientists, compared to the general public, have a very different understanding of what terms like "promise" or "breakthrough" mean. Non-scientists will generally impute considerably greater confidence to the assertions of scientists than do scientists themselves. While non-scientists read the "promise" of a promising scientific approach as exactly that—a guarantee, in good faith, that an approach *will* yield an expected outcome—scientists see "promise" as no more than a prediction of *likely outcome.* Promising areas of research are merely interesting ones, worthy of pursuit and likely to yield the expected finding. Should the "unlikely" prove to be the case, most scientists would find this result quite interesting and would in no way see such a turn of events as a breach of "promise." Reversals of

7. A recent search of the Computerized Retrieval of Information on Scientific Projects (CRISP) database at the National Institutes of Health (NIH) (http://commons.cit.nih.gov/crisp3/Crisp_Query.Generate_Screen) for the 2002 funding year revealed 198 grants to individual investigators that have been continuously funded for between 30 and 35 years, with five projects that have been continuously funded for more than 45 years. *See* NAT'L INSTS. OF HEALTH, CURRENT AND HISTORICAL AWARDS (1972–2003) QUERY FORM, *at* http://commons.cit.nih.gov/crisp3/Crisp_Query.Generate_Screen (last visited Jan. 24, 2003) (on file with author).

expectation happen so frequently in scientific research, one must simply take them in stride and not look back. Assertions of "promise" from scientists are best taken with the same gravity as assertions of unending love from a confirmed philanderer; while commitment to a specific hypothesis may be made in genuine sincerity at the time, with the full support of the existing evidence, such commitments last only until a more attractive data set comes along. While such "flexibility" might be unattractive in personal behavior and imprudent as a basis for public policy, it is essential in the practice of science.

Similarly, scientists will often characterize exciting results as "breakthroughs," asserting that the findings now "prove" a particular feat can in fact be accomplished. While most people believe "breakthroughs" have important implications for the treatment of disease or injury, this is usually far from the case. For scientists, a breakthrough merely refers to findings that significantly advance our *understanding* of a phenomenon. A breakthrough may represent a very interesting intellectual answer to a nagging or intractable puzzle—but it doesn't necessarily translate into a practical or medical application. As stated above, science is about defining the possible. A breakthrough may bring into the realm of the possible that which was previously excluded, but possible is not the same thing as feasible or practical.

For example, under experimental conditions, manipulating gene 'X' may result in complete remission of an otherwise lethal disease. Scientists would readily characterize such a finding as a "breakthrough" that "proves" a cure is possible. Nonetheless, due to the fact that such manipulations can be done in experimental animals only at very early embryonic stages, it is not now the case, nor is it ever likely to be the case that genes in patients will be manipulated in the same manner to cure human disease. Thus, while a cure is now within the realm of the possible (under highly restricted experimental conditions), it is by no means within the realm of the practical. Assertions of "proof" and "breakthrough" need to be judiciously classified, either as proofs of *principle* (that something can be done under laboratory conditions) or proofs of *practice* (that something can be done under real-life conditions).

B. *Forever Further Research vs. "Done Enough"*

Vannevar Bush, head of the Office of Scientific Research and Development in the middle of the last century, authored a proposal for the creation of a government-funded national scientific agency, entitled "Science, The Endless Frontier."[8] While the title was surely intended to convey the essential optimism and limitlessness of science, the ironic truth is that "endless" suggests "interminable" as equally as it does "limitless." In the face of unproductive, or merely "promising" results, optimistic scientists frequently invoke the endless frontier of science under the general panacea of "further research is required." There is always one more experiment to do or one more technique to try that may turn a negative finding into a positive one. For a particularly compelling hypothesis, this process of tinkering and hoping can indeed stretch on interminably, even in the face of substantial data opposing the hypothesis. Rarely is a hypothesis strictly disproved by the data. An idea can be disproved in this particular circumstance, under these specific conditions—but there is always hope that these conditions may be the exception rather than the rule. The endless frontier of science can easily become one of perpetual hopeful exploration with no particular end point in sight.

The most significant negative effect of the endless scientific frontier is the reluctance of scientists to call it quits or to consider the relative merit of scientific endeavors in the face of pressing competition for limited public resources. Almost instinctively, scientists will advocate "further research" as the answer to any and all objections raised to a particular line of experimentation, particularly if the objection is that the research has failed to yield the anticipated societal benefit. To a scientist, interesting lines of experimentation are intrinsically valuable, regardless of their applicability to real world situations. This mindset significantly impairs the ability of scientists to make even prudential judgments regarding scientific research. From a practical point of view, the pure pursuit of knowledge must be weighed against the cost. While there are many cases in which future research will resolve questions that are at this time unresolved—there are equally many in which further research is unlikely to alter the current state of affairs. Due to their essential optimism and focus on what *may* be possible, scientists cannot be counted on to reliably make such distinctions.

Just as the practical applications of scientific research are limited by the endless pursuit of interesting research, they are equally limited by the failure to bring to a practical completion lines of research that are no longer interesting. Scientists readily

8. VANNEVAR BUSH, SCIENCE, THE ENDLESS FRONTIER: A REPORT TO THE PRESIDENT ON A PROGRAM FOR POSTWAR SCIENTIFIC RESEARCH (Nat'l Sci. Found. 40th Anniversary ed. 1990).

abandon investigations as uninteresting once the essential question has been resolved. Resolving the central question often leaves many aspects of the problem that are critical for a practical application entirely unaddressed. The need to address critical, although perhaps less scientifically interesting, questions also falls under the panacea of "further research is required." The difference is merely that such "uninteresting" research is always assumed to be the responsibility of someone else, and consequently is rarely accomplished. Unfortunately, the pharmaceutical industry is generally reluctant to pick up on "promising" scientific findings that are still full of practical holes and uncertainties. Thus, while the "promise" of such abandoned lines of research may be real, it is never actualized.

In evaluating the "promise" of a promising scientific approach, it is important to consider evidence that contradicts or restricts that promise, as well as the evidence supporting it. A proof in principal may not constitute a proof in practice. The holes in our understanding that preclude a practical application of a promising finding may never be filled, despite a commitment of funds to further research. In a world of limited resources, judgment calls must be made. The reluctance of scientists to make such judgments based on the evidence is not an excuse for policy makers to do the same.

C. *"Don't tell me what to do"*

The risks and speculation involved in the formation and testing of a scientific hypothesis requires a particular type of individual. Scientists are not mavericks (science is too dependent on established facts to favor rebels who reject the conventional), but rather individualists who are willing to take any idea and run with it. The highly complex and specialized nature of scientific information only serves to exaggerate and reinforce the individualistic tendency. It is surprisingly easy to be "the world's leading expert" in a particular field—simply because "the field" may consist of only a handful of other scientists interested in the same questions and capable of intelligently discussing them. Scientists in disciplines as related as neurobiology (the study of how cells in the nervous system function) and neuroscience (the study of the how the nervous system itself functions) can find it difficult to communicate with each other at times, due to the specialized information and terminology required to be proficient in each of these fields.

The specialized nature of scientific information and the complexity of the terminology contribute to a profound sense of autonomy, and an unwillingness to accept input from those perceived as "unqualified" to levy reasonable criticism. Even among fellow scientists, those deemed worthy to evaluate and restrict an individual's research program are few and far between. Scientists frequently lament the inadequacy of peer review for grants and manuscripts—with the most common complaint being the "ignorance" of the reviewers and their consequent "incompetence" to evaluate the data. If scientists are reluctant to accept evaluation and restriction from other scientists, how much more so are they unwilling to be constrained by the judgments of non-scientists?

The optimism and individualism of scientists results in an exaggerated, "knee-jerk" unwillingness to be told what to do. The sentiment underlying many of the advocacy positions taken by scientific societies appears to be: Leave us alone to do as we see fit, you who cannot understand or evaluate what we are about. The reluctance of scientists to accept oversight is only heightened by what scientists frequently perceive as ignorance and suspicion in the mind of the public.[9] Regrettably, there is some truth in the view that the public is scientifically illiterate. Irrational or unfounded objections to scientific findings only serve to confirm scientists in their opposition to oversight. Nonetheless, the resistance of scientists to external regulation is itself quite irrational. While concerns regarding scientific advances range from the well founded to the absurd, from the mindset of most scientists, *all* opposition is absurd.

At their cores, scientists are motivated by curiosity. While a desire to understand simply for the sake of understanding is certainly an advantage in scientific endeavors, curiosity itself does not guarantee the object of investigation is worthwhile or beneficial to society. There are no necessary limits to scientific curiosity—not even the limits of decency. History provides ample illustration of how the free pursuit of science must be restricted under some circumstances. The infamous experiments of Milgram[10] or the Tuskegee Syphilis study,[11] to give only two examples, are the kind of science some may elect to pursue if left with only "scientific curiosity" as a guide. Endorsing scientific research simply because it is interesting and it *might* prove useful is a dangerous path with no clear guideposts. Much "useful"

9. *See* NAT'L SCI. FOUND. PUBL'N CLEARINGHOUSE, SCIENCE AND ENGINEERING INDICATORS 2000, *at* http://www.nsf.gov/sbe/srs/seind00/start.htm (June 5, 2002) (on file with the Notre Dame Journal of Law, Ethics & Public Policy).

10. *See* Stanley Milgram, *Some Conditions of Obedience and Disobedience to Authority*, 6 INT'L J. PSYCHIATRY 259–76 (1968).

11. R.H. Kampmeier, *The Tuskegee Study of Untreated Syphilis*, 65 S. MED. J. 1247–51 (1972).

information can be derived from experiments that are objectively evil. The ends, no matter how noble, cannot justify any and all possible means. The challenge to society is: How will the line be drawn, and by whom? By virtue of their disposition and their focus on "the possible," scientists are not particularly well-suited to make such prudential judgments.

D. *Scientific Gnosticism*

Discovery of something new is inarguably a thrilling experience. But this thrill, when combined with a fiercely independent nature and a subject matter far removed from common experience can fuel a scientific demagoguery and gnosticism. "Gnosticism" is the generic name given to a collection of religious sects that waxed and waned from the 5th century B.C. to the time of Constantine.[12] The unifying theme of these cults was the belief that their members possessed special, secret knowledge that separated them from the uninitiated masses.[13] Possession of this knowledge allowed the believer to see things as they "really are" and thereby gain salvation.[14] An inevitable air of superiority surrounded the Gnostics because the "knowledge" they possessed afforded them an allegedly more perfect view of reality.[15]

The scientist who discovers something truly new, after years of hard work, is naturally susceptible to the temptation to make more of the discovery than is warranted. A clique can easily form around the discovery to include all those who are "in the know" and exclude those who "don't understand how this changes everything." Just as with religious Gnostics, scientists come to believe that the "special knowledge" scientific information provides elevates their opinions and judgments above those of anyone else. Other forms of understanding come to be seen as inherently limited, flawed, or "quaint."

It is important to remember that while science readily produces new and unique instances of things heretofore unknown, it rarely (very rarely) uncovers something that undermines the *principles* by which *all instances* should be judged. Mere creation of a new virus or a new form of animal by the wizardry of molecular biology does not alter the rules governing prudent and moral

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12. For the general treatment of Gnosticism as given here, see WILLIAM A. REESE, DICTIONARY OF PHILOSOPHY AND RELIGION: EASTERN & WESTERN THOUGHT 260–61 (1996), and NEW ADVENT, CATHOLIC ENCYCLOPEDIA, *at* http://www.newadvent.org/cathen/06592a.htm (Dec. 2, 2002) (on file with the Notre Dame Journal of Law, Ethics & Public Policy).

13. REESE, *supra* note 12, at 260–61.

14. *Id.*

15. *Id.*

treatment of viruses and animals. Correctly *classifying* new discoveries and scientific creations can present a real challenge that critically requires the input of scientists, but once the nature of the "new reality" is understood with confidence, standard principles of judgment and precedent apply to new and old realities alike.

It is also important to remember that scientific understanding does not render other forms of human understanding obsolete or irrelevant. The scientific understanding that the human body contains cells, which in turn contain DNA does not "trump" a parent's understanding of a particular human as their child or an ethical understanding of that child as a member of the human race. Having a scientific understanding of the human body may be required to evaluate a proposed experimental medical treatment, for example, but it does not reduce a child to a collection of chemicals and cells. In practice, any scientific understanding a parent may have is likely to make only a very minor contribution to the overall understanding of their child. Importantly, scientific information does not relieve even the most scientific parents of the *obligation* to make decisions regarding their children in the most comprehensive and just manner possible; as a scientist, as a parent and as a citizen—under the law and under God. The same obligation holds on a larger scale for those charged with making legislative and policy decisions for society.

VI. Scientists as Practitioners and Businessmen

Just as physicians are individuals engaged in the practice of medicine, scientists are individuals who practice science for a living. While this may seem absurdly obvious, the myriad ways in which the roles of scientists as practitioners and businessmen limit the utility of expert scientific testimony appear to be largely misunderstood (or perhaps simply ignored) by policymakers and the public alike. Misperceptions of how the business of science operates result in the public assigning both too little and too much credibility to the opinions of individual scientists.

A. *Money and the Ttruth*

The most popular misperception of scientists as practitioners is that funding mechanisms put economic pressure on researchers to conform their results to a foregone conclusion. The belief is that when a scientist takes money from the NIH or from private industry to test a specific idea, the ensuing research is virtually guaranteed to prove that idea correct. The motivation for this manipulation of the truth is presumed to be money. Scientists will follow the money and manufacture data that allows them to stay in the money. A growing number of patient advocacy groups lobby aggressively for increased funding targeted to specific diseases, based precisely on this misperception.

The first and most significant problem with this hypothesis is that in most cases, there is very little relationship between research funding and the personal financial status of the scientist. The vast majority of basic scientists is employed by universities or research institutes.[16] As academic or research faculty, the salaries scientists earn are not proportionate to the level of funding their research programs enjoy. There are no year-end bonuses or hefty commissions in academic science. For scientific faculty, salaries typically remain constant whether scientists have ample research funding or no funding at all. While there certainly are situations in which personal profit must be a consideration,[17] in the majority of circumstances "greed" *per se* is not a major factor in the pursuit of research monies.

This is not to say that scientists are unmotivated to maintain and increase research funding. Scientific research is astoundingly expensive. A single experiment in modern molecular biology can typically cost thousands of dollars in supplies alone. Without external research funding, universities and research institutes would be unable to support the cost of research. Moreover, the vast majority of research personnel in a laboratory (technicians, doctoral students, postdoctoral trainees) is paid directly from research grants, and are not employees of the university or institute. Thus, while scientists are not motivated to secure and expand funding by personal greed, they are highly motivated by the simple fact that without funding, they will be unable to do their research at all.

The consequences of losing research funding can be catastrophic. No one relishes the thought of having to fire long-term colleagues, collaborators and students due to a lack of funding. In addition, a temporary loss of research funding can readily

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16. Statistics maintained by the National Science Foundation for 1999 (the most recent year available) indicate that of 110,700 persons holding a doctoral degree in Biological Sciences, 79,500 are employed by academic or research institutions, compared to 19,700 employed by industry, 10,100 by governmental agencies and 1,400 who are self employed. SCIENTISTS AND ENGINEERS STATISTICAL DATA SYSTEM, CHARACTERISTICS OF SCIENTISTS AND ENGINEERS IN THE UNITED STATES, *at* http://srsstats.sbe.nsf.gov/preformatted-tables/1999/DST1999.html (June 20, 2001) (on file with the Notre Dame Journal of Law, Ethics & Public Policy).

17. *See infra* Part VI.C.

become a permanent condition. Without money for reagents and personnel it is virtually impossible to generate data, and successfully competing for research funding requires preliminary data to support the feasibility of the proposed experiments. Fear of being trapped in such a "Catch-22" is very real, and a strong motivator for most scientists to seek secure research funding. Fear of losing funding due to factors that are outside of one's direct control is also quite real. In many cases, budgetary rather than scientific reasons dictate research funding decisions. Indeed, many divisions of the NIH routinely fund no more than 20% of all applications they receive, with several Institutes funding considerably less.[18] Scientists charged with evaluating the quality of grant applications routinely express concern over the number of excellent proposals that fall into this lower, unfunded 80%.[19] All of these concerns translate into a strong motivation to "diversify" the sources of research funding in an attempt to keep overall funding levels as stable as possible.

The major sources of research funding are federal and local government (principally the NIH for biological and medical research), charitable foundations, and private industry.[20] To competently weigh scientific testimony on topics that may affect these sources of research support, the relationship between scientists as practitioners and their research funding must be realistically understood.

B. *Government Funding*

How does the motivation to maintain a stable source of research funding affect the nature or quality of the scientific findings resulting from that funding? Surprisingly, for research

18. Statistics maintained by the NIH indicate that "success rate" (*i.e.*, the percent of grants submitted by individual investigators that are funded) varies greatly between the Institutes. In 2001, a historically good year for funding, individual institutes ranged between a 15% and 40% success rate. NAT'L INSTS. OF HEALTH, AWARD DATA, *at* http://grants.nih.gov/grants/award/award.htm (Jan. 6, 2003) (on file with the Notre Dame Journal of Law, Ethics & Public Policy).

19. Statistic derived from the author's personal experience.

20. Statistics maintained by the National Science Foundation indicate that in 2000, the most recent year for which data is available, funding for research at Universities and Colleges totaled $30,062 million, of which $19,697 million (approximately 65%) came from government sources, $2,178 million (~7%) from industry, $5,924 million (~20%) from foundations, and $2,261 million (~8%) from all other sources. NAT'L SCI. FOUND., ACADEMIC RESEARCH AND DEVELOPMENT EXPENDITURES: FISCAL YEAR 2000, *at* http://www.nsf.gov/sbe/srs/nsf02308/sectb.htm#rd2 (Feb. 2000) (on file with the Notre Dame Journal of Law, Ethics & Public Policy) [hereinafter DEVELOPMENT EXPENDITURES].

funded by the federal government and private foundations there is very little impact. A truly extraordinary feature of government and foundation-sponsored research is that the likelihood of renewed funding is more dependent on productivity and impact than on the precise nature of the findings. As noted above, reversals of expectation are common in science. It is just as frequent for a hypothesis to be invalidated as it is for the hypothesis to be proven true. Consequently, there is considerable pressure to resolve the question one way or another (*i.e.*, to advance the field), but very little pressure to demonstrate the expected finding. Well-designed experiments are informative regardless of their outcome—and fierce competition for limited research dollars generally ensures that funded experiments are well-designed. Thus, while it may appear that the push for ever-more research funding and the competition for research dollars would provide an incentive to generate ever-more positive findings, in practice this is rarely the case.

In contrast, the inherent insecurity of research funding and the competition for research dollars can strongly influence the opinions of scientists regarding the appropriate level of public resources to be devoted to scientific research. Science journalist Daniel Greenberg has amply documented that scientists protest the "inadequacy" of the NIH budget, despite a consistent growth in this budget over the last forty years.[21] Scientists will advocate increases in NIH funding, even when appropriated funds are not targeted towards their own areas of research, simply out of a conviction that a rising tide floats all boats. When a scientist's own research program stands to profit directly from a greater availability of funds, this tendency is understandably even stronger. Importantly, scientists advocate greater funding not out of a reasoned consideration of what level of research funding is most appropriate to the overall interests of society, but rather out of a personal conviction that *all* "good research" is inherently valuable and should be funded. Unlike business or engineering where one can reasonably ask, "How much will it take to get the job done?," in the endless frontier of science, the job is never done and no amount of funding is ever enough. The scientific mindset and the practical constraints of research funding restrict the ability of scientists to make sound prudential judgments regarding science funding. Consideration of what kinds of research to fund and at what level must be made within the

21. Daniel S. Greenberg, Science, Money, and Politics: Political Triumph and Ethical Erosion 78–88, 183–204 (2001).

broader view of society's priorities, impassioned testimony of scientists not withstanding.

C. *Private Industry Funding*

For an increasing number of scientists, stable research funding is found through private industry. The percentage of research funding from private industry has grown consistently over the last twenty years and currently hovers around 7% of all academic research funding in the United States.[22] Accepting money from private industry to test a specific hypothesis does carry some pressure to produce a positive finding. If a pharmaceutical company awards a substantial sum of money to test whether a new drug is effective, they are unlikely to find either outcome of this experiment equally desirable. Nonetheless, the risk of scientists manipulating their data to curry the favor of industrial sponsors is quite slim. Even in the absence of any high-minded commitment to the truth, the fear that the company will refuse to fund additional research in the face of an undesirable outcome is generally balanced by the equally strong fear that falsified or misleading data will ultimately be uncovered. Thankfully, the culture of science does not select strongly for the craven or the unscrupulous. The personal rewards are too few, the chance of disgrace too high, and the career path too arduous to favor those interested in easy money at the expense of the facts.

In recent years, the relationship between biomedical research and commercial ventures has become more complex. In addition to industry grants and partnerships, an increasing number of academic scientists are directly involved in the growing biotechnology industry. Scientists are frequently founders, board members and major stockholders or both in start-up biotechnology firms that are positioned to exploit research results with real (or perceived) marketing potential. In many cases, scientists hold primary patents on the products these companies are developing. Many of the prominent scientists whose opinions are actively solicited by the media and by governmental leaders are far from "disinterested" in the outcome of science policy decisions. While this has been true for some time in the field of engineering, it is a relatively new phenomenon for biomedical research. The potential for a direct conflict of interest in the recommendations of scientists has become quite significant and must not be ignored when considering the purportedly "unbiased" expert testimony of scientists. Even mere public advocacy

22. DEVELOPMENT EXPENDITURES, *supra* note 20.

of specific research policies must be considered in light of the direct financial interest scientists may have in the outcome of the debate.

VII. Popular Myths

The popular myths surrounding the scientific profession are complex and contradictory. In many respects, society affords scientists great esteem as demigods of technology. The public and the press tend to see scientists more as saints and heroes than as mere practitioners of science and developers of technology. Somehow, scientists are "different" from the rest of us—brilliant, focused, and above all else, committed to objectivity and the pure pursuit of knowledge, untainted by self-interested or worldly concerns. Scientists are subject to this same type of mythical thinking, a tendency that only serves to reinforce and exaggerate scientific Gnosticism.

Equally compelling in the collective consciousness is the view that scientists are hopelessly naïve and unsuited to participate in the "real-world" decisions of politics. The most common image of a scientist offered by popular entertainment is that of a bumbling (although well-intentioned) maladroit who unwittingly releases a lethal virus on the populace, requiring a policeman or other "real-world" hero to save the day.[23] This negative myth of the scientist occasionally takes more extreme and darker forms. The power of science and the complexity of scientific information can fuel fears of the "mad-scientist"; an evil genius who uses the magic of science to advance his own inscrutable (or unscrupulous) plans.[24]

As in all myths or stereotypes, there is a certain grain of truth in these perceptions. Obviously, scientists are in possession of a certain measure of intelligence, although the level of "brilliance" required to be successful in the profession is perhaps not as high as one would imagine. As a class, scientists are relatively uninterested in material things (a trait many would define as "geekishness"). When compared to physicians or attorneys, scientists are woefully under-compensated for their level of education, providing some direct evidence for a lack of worldliness.

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23. For example, in the movie "Outbreak" (1995), an important breakthrough by scientists goes awry and the release of a virus that could kill millions is prevented by the "real world hero" First Sergeant Dutton Hattfield.

24. One study indicates that negative television portrayals of scientists (as killers, for example) are considerably more common than negative depictions of other professionals. George Gerbner, *Science on Television: How it Affects Public Conceptions*, 3 Issues Sci. and Tech. 109–15 (1987).

With rare exceptions, scientists are passionately committed to objectivity and the truth, characteristics without which one generally doesn't proceed too far in a field where the "truth" is readily verifiable by anyone with a mind to test it and the resources to do so. As individualists, scientists are prone to defining their research on their own terms, a trait that can lead to substantial disregard for the social impact of scientific discoveries. This disregard for public opinion or societal impact ("don't tell me what to do") lends credibility to both of the negative scientific stereotypes (*i.e.*, the "bumbling" and the "mad" scientist), although sociopathology is surely no more prevalent among scientists than it is among other professionals. Clearly, none of these characteristics are restricted to the scientific profession, but they are typical of scientists in general.

Nonetheless, the popular perception of scientists as either heroes/gods or fools/egotists is largely unfounded. Daniel Greenberg goes to great length to debunk many of the hallowed myths surrounding scientists and how they function.[25] Scientists, as it turns out, are human beings—subject to the same kind of failings and confusions that plague other members of the species. The self-evident conclusion that scientists are merely human apparently came as quite a surprise to Mr. Greenberg. The fact that this topic warranted a treatise of 530 pages (replete with appendices, tables, and statistics to bolster the obvious) provides evidence for the powerful influence of myths and stereotypes in our cultural thinking about scientists and their profession.

Popular myths that are resistant to the obvious are by no means limited to the scientific profession. Many would assert with sincerity that doctors are "noble," firemen are "heroes," and grade-school teachers "saints." The surprising thing about the myths surrounding scientists is the robustness of these myths and their abilities to preclude common-sense judgments. Most people, when faced with an individual physician, fireman, or teacher, will evaluate them as individuals—with appropriate skepticism and caution with regard to their motives and intentions. Not so with scientists. While we may not want our child to marry one (they are, after all, geeks), we trust them implicitly on matters of science and science policy. The equation appears to be: How can mere laymen hope to fathom the arcane depths of knowledge scientists possess or doubt their commitment to objectivity and the truth?

25. GREENBERG, *supra* note 21.

The robust myths surrounding science lead society to give the personal opinions and policy recommendations of scientists far greater weight than they merit. A science policy position signed by prominent Nobel Laureates has much greater social impact than a business policy position signed by a similar number of Fortune-500 CEOs. Regardless of how successful a businessman has been and how admired he may be for his business acumen, his motives are perceived to be too tainted by profit to be altruistic. In the modern age, we take the assertion, "what's good for General Motors is good for America," with considerable skepticism. Yet we readily accept the parallel construction from scientists ("What's good for research is good for America"), based in large part upon the myth of scientists as heroes and gods.

To define an appropriate limit to the mandate of scientists and their influence on public policy, society must recognize the power of this myth and actively work against it. In part, this requires making an effort to be reasonably literate in scientific matters. Having some knowledge of science goes a long way towards demystifying the field and provides a personal basis for rationally evaluating scientific evidence. Yet even with considerable effort, mastery over *all* of modern molecular biology would not be possible. Scientific information is simply too complex and the body of scientific knowledge too large to circumvent the requirement for expert testimony from scientists.

In light of the inherent dependence policy makers have on scientists to summarize scientific information, it is important to draw a distinction between what a scientist needs to know about a particular topic and what is required for the formation of sound policy. Evaluating whether a highway should be built in Tuscaloosa does not require a detailed understanding of how to pour concrete in the hot and humid weather found in those parts (regardless of how a civil engineer may see the matter). Such an evaluation *does* require an understanding of where the road will lead and what purposes it will serve. Evaluating public policy on genetic engineering, embryonic stem cells, or human cloning similarly does not require a detailed understanding of the underlying technology—but rather a willingness to weigh the issues raised by this technology in a broader social context without merely deferring to the judgment of scientists or relying unduly on vague assertions of "promise."

CONCLUSIONS

Navigating uncharted waters at the frontier of scientific research is inherently a difficult task fraught with danger. Scientific discoveries define as newly possible things that were previously only imaginary and raise significant moral and prudential issues for society. On moral issues, scientists are no more prepared to provide an intelligent answer than anyone else. In moral debates, the professional competence of the scientist is limited to a presentation of the facts that delimit the boundaries of the discussion. Yet even in cases of prudential judgment, the testimony of scientists ought not be trusted implicitly. Scientists as a group are optimistic in outlook, conservative in judgment, and fiercely independent in nature. Add to this the fact that many scientists have financial entanglements that can create conflicts of interest, and one must conclude that the "objective opinion" of the scientist must be examined very carefully. Factors that limit the credibility of scientific witnesses and restrict the utility of their testimony include:

- Scientific optimism can result in exaggerated claims regarding the practical applications of research.
- Terms like "promise," "breakthrough," and "proof" don't mean the same thing for scientists as they do for the general public; distinctions must be made between proof in principle and proof in practice.
- Further research and expanded research funding do not guarantee scientific "promise" will be brought to practical fruition.
- Scientists resist any form of regulation or oversight, no matter how warranted restrictions may be by social, economic, or ethical considerations.
- Scientific curiosity is unconstrained by either prudence or decency.
- Scientific understanding doesn't invalidate general principles or "trump" other forms of understanding.
- While scientists are typically not motivated by greed *per se*, they rarely see research funding levels as adequate.
- Many scientists have financial involvements in biotechnology that create significant conflict of interest.
- Robust myths notwithstanding, scientists are not saints or heroes, and their personal opinions should not be considered more rational, objective, or disinterested than those of anyone else.

In light of these considerations, what is to be done? How can the testimony of scientists be fairly and neutrally interpreted without requiring an extraordinary level of scientific literacy on the part of the public? In light of the foregoing discussion, a few practical recommendations are offered.

A. *Acknowledging Conflict of Interest*

Scientific experts must be subject to the same disclosure requirements regarding conflicts of interests that are applied to everyone else. Scientists are unlikely to provide completely unbiased testimony on topics that directly or indirectly affect the funding levels available for their own research or for biotechnology enterprises. The extent to which the research funding of the scientist's own laboratory may be altered by the outcome of the debate for which testimony is being solicited must be taken into account. This potential conflict can be at least partially circumvented by soliciting testimony from scientists outside of the immediate field who are able to provide expert scientific evaluation without immediate concern for the security of their own research funding. Moreover, testimony from scientists with direct financial interest in the outcome of legislation, including biotechnology patents and stock holdings in companies developing new technology (or both) should not be considered impartial. Such individuals should be obliged to recuse themselves due to the conflict of interest.

B. *Restricting Scientific Testimony to Scientific Facts*

Distinctions must be drawn between scientific findings and mere opinion. Expert testimony from scientists should be restricted to topics upon which they are, in fact, experts—the current state of our understanding and the facts upon which it is based. While scientists can be reasonably asked to summarize or explain the scientific evidence, their opinions on issues outside their areas of expertise (including moral or ethical issues) are no more credible than those of any other person. It is curious how many Nobelists in economics, physics, and chemistry (not to mention film celebrities) feel compelled to weigh-in as "experts" on matters of biological science[26]—and equally curious how

26. For example, recent statements by Nobel Laureates regarding stem cell research and therapeutic cloning have received extensive media attention and are frequently invoked in support of federal funding for stem cell and cloning research. *See, e.g.*, Morton M. Kondracke, *Congress Should Allow and Control 'Research Cloning'*, ROLL CALL, Apr. 15, 2002; Rick Weiss, *Nobel Laureates Back Stem Cell Research; Group of 80 Recipients Sends Letter Asking Bush Not to Block Funding for U.S. Studies*, WASH. POST, Feb. 22, 2001, at A02.

much respect appears afforded such opinions.[27] When presenting findings, scientists should be required to discuss *both* supporting and detracting evidence as well as provide a clear picture of what is not yet known with certainty. The optimistic tendency of scientists to focus on what is possible, but unproven, frequently results in an incomplete and misleading picture. Advocating public policy based on incomplete disclosure of the facts is not science—it is propaganda.

C. *Evaluating Assertions of "Promise"*

The culture of science makes certain kinds of myopic judgments highly probable. With great confidence one can predict that *regardless* of the specific scientific topic under discussion the testimony of most scientists will be: 1) the area of investigation has promise, 2) further research and increased funding are required, and 3) the progress of science must not be impeded by legislative restrictions. While such recommendations say a great deal about the culture of science and the personality traits selected by the profession, they say very little about the actual state of the scientific evidence.

Basing public policy or legislative decisions on unproven scientific "promise" is naïve and foolhardy. The "Missouri" approach ("show me the data") is an entirely appropriate response to optimistic scientific predictions of "promise." Scientists are generally quite capable (when pressed) of outlining what would constitute "proof of practice," and what would be required to generate such a proof. Pressing them to do so, without settling for the vague panacea of "further research" is both prudent and reasonable.

27. Celebrities have been increasingly solicited for testimony before Congress in recent years, a trend that has been noted more than once. *See, e.g.*, Malia Rulom, *Stars Come Out in Congress and One Senator Has Had Enough*, ASSOCIATED PRESS, June 6, 2002.