Genetics and the Law: A Scientist's View

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Introduction

Reality is often profoundly altered by scientific and technical innovation. These changes occur unexpectedly and swiftly. Yet many people in our society know nothing about science. They have no sense of the vast scientific world of people and ideas and knowledge. Although their own daily lives depend on scientific knowledge and its technical fruits, they are untroubled by their ignorance. Indeed, in spite of this ignorance they may still consider themselves, and be considered by others, to be well educated, intelligent, even intellectual. Unfortunately, this fantasy has serious consequences for science, for scientists and for society.

When, in 1956, I completed my formal education by satisfying the requirements for a Ph.D degree in biochemistry, I had already joined the scientific community. More than many graduate students in the sciences, however, my friends and acquaintances were drawn from outside science. My husband was a law student while I was in graduate school, and I moved, as a spouse does, within his law school community. As a consequence, I learned informally such things as why the Supreme Court matters and how the Constitution remains a flexible foundation for modern American society. I learned the names and accomplishments of the law school professors. I was on the scene for some of the great political debates of the McCarthy era. I even committed to memory the lengthy names that identify famous law firms. Oddly, it never occurred to me that the law students whose studies so interested me never asked what I did. Our conversations never extended to biochemistry or, for that matter, any other science. No one discussed my professors' latest theories or experiments. Most, if not all, law students remained unaware of the bombshell dropped by Watson and Crick in 1953, an event at least as important as the rise and fall of Joseph McCarthy.[1] I did not realize then that though we lived in the same country, spoke

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1. In 1953, James D. Watson, an American biologist, and Francis H. Crick, a British biologist, proposed the double-helical structure of the DNA molecule, a structure instru-

the same language, and attended the same university, I lived largely in a separate world, a world governed by fundamentally different customs and assumptions, with its own heroes and scoundrels and rookies of the year — the world of science.

As the years passed, the rift between the worlds of science and law became more apparent to me. Those then young law students, now prominent and successful attorneys, judges and policy-makers, have remained, with few exceptions, oblivious to my world. The current generation of young lawyers, law students and those vying for places in the country's law schools is little different.

Times, however, have changed. Today, even more than when I was a student, science has a major impact on people's lives. Much of the impact is positive, but it is, like many good things, associated with problems. Often the resolution of these problems falls not on scientists, but on lawyers, those same lawyers who for the most part remain ignorant of science's ways.

This article gives a scientist's view of the legal community's special obligations toward scientific issues, obligations incurred as advocates, judges, legislators and policy-makers. This view reflects experiences arising from my involvement, over more than a decade, in the issues and public debates concerning genetic engineering (also called recombinant DNA technology and gene cloning). The article first describes the widening rift between the worlds of science and law. Then, by considering the historical example of the Soviet agronomist, T.D. Lysenko, it examines the possible consequences of allowing those ignorant of science to evaluate its significance and impact. Beginning in the early 1930's, Lysenko succeeded in replacing scientific reality with political ideology as the basis for Soviet policy on genetics. Under his guidance, genetic realities were officially ignored in order to promote ill-founded theories of inheritance that were viewed by those in political power as better suited to Soviet ideals. Lysenko held sway for more than thirty years. The results of his reign were disastrous — Soviet agriculture suffered setbacks from which it has still not fully recovered, and the U.S.S.R.

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mental in explaining the method of duplication of genetic material and the ways in which genetic information is expressed.

Their discovery, a critical development in biology in the twentieth century, has been heralded as "an achievment of imagination that rivals the parallel enterprise in physics that began with relativity and quantum mechanics." Hudson, *Annals of Science*, THE NEW YORKER, November 27, 1978, at 47.

For a personal account of the discovery of DNA's structure, *see* JAMES D. WATSON, THE DOUBLE HELIX (1968).

was left without a community of trained geneticists capable of beginning to undo the damage.

After reviewing the example of Lysenko, I examine the current activities of Jeremy Rifkin, a Washington lobbyist and writer who plays on public ignorance about science in attempting to thwart, even prohibit, genetic engineering. Mr. Rifkin's arguments and style are persuasive. However, they deny and ignore much of scientific knowledge and turn instead on people's unfounded fears. His attack on recombinant DNA experimentation, though it comes at a different time and in a different political system, poses a threat in the United States not unlike the Lysenko debacle in the U.S.S.R.. Rifkin, like Lysenko, counsels us to ignore scientific realities in favor of ideology. In so doing, he defeats efforts, rooted in scientific arguments, to deal rationally with the serious questions raised by genetic engineering and to foster coherent public debate.

Finally, the paper makes a proposal that addresses the difficulties involved when lawyers are called upon to resolve scientific issues. The proposal is neither dramatic nor novel. It is, quite simply, education.

I. *The Two Cultures*

I was made conscious of the gap between scientists and lawyers by a short book published in 1959 and boldly entitled "The Two Cultures and the Scientific Revolution."[2] Its author, Sir Charles P. Snow, was a distinguished British scientist and novelist, and thus uniquely prepared to write such a book. The book was a major event. It was generally agreed that the chasm Lord Snow described was real and important and required fixing.[3] But the book, then so widely acclaimed, is now largely forgotten, and the situation has, if anything, grown worse.[4]

In 1959, Snow wrote:

> In fact the separation between the scientists and non-scientists is much less bridgeable among the young than it was even thirty years ago.

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2. C.P.Snow, The Two Cultures and the Scientific Revolution (1959).

3. Between the literary intellectuals at one pole and the physical scientists at the other, Snow saw "a gulf of mutual incomprehension — sometimes (particularly among the young) hostility and dislike, but most of all lack of understanding. They have a curious distorted image of each other. Their attitudes are so different that, even on the level of emotion they cannot find much common ground." *Id.* at 4-5.

4. Snow himself seemed to fear that the urgency of the problem would not hasten its resolution. "Isn't it time we began [to close the gap]? The danger is, we have been brought up to think as though we had all the time in the world. We have very little. So little that I dare not guess at it." *Id.* at 54.

> Thirty years ago [in 1929] the cultures had long ceased to speak to each other: but at least they managed a kind of frozen smile across the gulf. Now the politeness has gone and they just make faces.[5]

The physicist Richard P. Feynman illuminates the problem from a different perspective:

> It does not do harm to the mystery to know a little about it. For far more marvelous is the truth than any artists of the past imagined! Why do the poets of the present not speak of it? What men are poets who can speak of Jupiter if he were like a man, but if he is an immense spinning sphere of methane and ammonia must be silent?[6]

Lately, the mutual understanding between the two cultures has decreased even more. The need for such understanding, however, has grown. Biology, including genetics, is particularly important because it is the science which speaks to the fundamental nature of human beings. For a long time, biology was a descriptive science. Recently, with the advent of genetic engineering techniques, it has become a manipulative science — a technology, if you will. With this development, biology's potential for both good and evil has grown. Societal evaluation of this potential, which in our country involves legislative or judicial review, is now essential. Are lawyers, those called upon to perform the reviewing, up to the task?

Consider the following quotation:

> A little over a decade ago scientists developed the capability of modifying genetic material in the laboratory. Through a process of splitting and recombining a subcellular unit known as DNA, laboratory scientists could begin to control the natural processes of organism reproduction and growth. The product of this process of altering natural hereditary material is generally known by the name 'recombinant DNA.' The use of this technique has been limited to small organisms, usually bacteria.[7]

This quotation is not from a scientific journal, or even from the science pages of the *New York Times*. It is taken from a decision signed in May 1984 by Judge John Sirica of the U.S. District Court for the District of Columbia. Did the judge's training and knowledge provide a reasonable basis for writing this paragraph? Could the lawyers before the court understand this paragraph? Well enough to know whether it is accurate and precise in nuance?

Here is another example:

> 'Evolution-science' means the scientific evidences for evolution and in-

5. *Id.* at 19.
6. RICHARD P. FEYNMAN, THE FEYNMAN LECTURES ON PHYSICS 3-6 (1963).
7. Foundation on Economic Trends v. Heckler, 587 F.Supp. 753, 755 (D.D.C. 1984), *aff'd*, 756 F.2d 143 (D.C. Cir. 1985).

> ferences from those scientific evidences. Evolution science includes the scientific evidences and related influences that indicate: (1) Emergence by naturalistic processes of the universe from disordered matter and emergence of life from nonlife; (2) The insufficiency of mutation and natural selection in bringing about development of present living kinds from simple earlier kinds; (3) Emergency [sic] by mutation and natural selection of present living kinds from simple earlier kinds; (4) Emergence of man from a common ancestor with apes; (5) Explanation of the earth's geology and the evolutionary sequence by uniformitarianism; and (6) An inception several billion years ago of the earth and somewhat later of life.[8]

Is that an accurate description of evolution science? Would most lawyers, had they been members of the Arkansas State Legislature in 1981 called upon to vote on the Balanced Treatment for Creation Science and Evolution Science Act[9], have known whether it was rational and honest to vote for a law that included such a definition? Would they have been competent to stand in U.S. District Court Judge William R. Overton's shoes in 1981 and 1982, deciding whether to enjoin the Arkansas Board of Education from implementing that Act?[10]

We have in this country a fair array of local, state and federal legislators, many fine judges, and a mass of competent lawyers. Their common sense and integrity are not at issue. However, as the issues they face increasingly include a technical component, their common sense and integrity become insufficient. Presently, most lawyers and judges are incapable of dealing adequately with technical issues. The reason is simple; about the time they graduated from junior high school, give or take a few years, they, like many others, decided not to learn any more science. Their ignorance mirrors the ignorance of the citizenry, including most of those in this country who exercise power — whether intellectual, political, institutional or financial.

Americans as a whole, like their leaders, are curiously schizophrenic about the technological society in which they live. Deeply ignorant and distrustful of scientific ideas and progress, they nevertheless have an insatiable appetite for the products of scientific research. It seems impossible to determine, by any rational analysis, where distrust may overcome desire. For example, it is difficult to understand how people who without qualms demand the promiscu-

8. ARK. STAT. ANN. §80-1666 (1981 Supp.).
9. ARK. STAT. ANN. §§80-1663 to -1666 (1981 Supp.).
10. McLean v. Arkansas Bd. of Educ., 529 F.Supp. 1255 (E.D. Ark. 1982).

ous use of antibiotics for their child's every cold — a truly dangerous practice — can then turn around and express grave fears over the small amount of radiation released at Three Mile Island.

II. *The Consequences of Ignorance*

When people make choices for themselves, scientific ignorance may expose them to dangers at the personal level. The more serious dangers of scientific ignorance, however, occur when choices are made at the societal level. At this level, even a single individual can manipulate scientific ignorance and consequent fears into support for irrational, almost primitive myths. Such campaigns have often been the tools of established, powerful people and institutions — as when the Inquisition declared that Galileo must be wrong in his assertion that the earth rotated around the sun, or when Stalin declared his support for T.D. Lysenko's erroneous theories of agronomy. The Lysenko example is particularly pertinent. The outspoken and powerful support afforded this single individual and his ideologically popular but scientifically invalid theories led to a disaster in Soviet wheat production and delayed the development of modern genetics in the U.S.S.R.

For thirty years, beginning in the 1930's, this admittedly poorly educated agronomist dominated biology in the Soviet Union by dominating genetics. In the 1930's, Lysenko declared that classical genetics was all wrong. He rejected the idea that genes exist; he repudiated the established fact that chromosomes carry hereditary information; he insisted that characteristics acquired during the life of an organism could be passed on to progeny; he dismissed agricultural breeding practices that had been in use for centuries and were entirely consistent with standard nineteenth and twentieth century genetic concepts. He successfully established his ideas as official Soviet policy.

The basis for the acceptance of Lysenko's conclusions, which implied the abolition of genetics, was neither experimental fact nor a conflicting scientific theory. Only one so-called experiment was ever offered in support of the new Soviet genetics. It involved the production of a spring wheat variety from a winter variety. Lysenko felt that this transformation showed that, "there are no immutable genes for winter habit, and all depends on the environment: hence there are no genes of any kind."[11] This experiment, however, was

11. Z.A. MEDVEDEV, THE RISE AND FALL OF T.D. LYSENKO 22 (1969).

methodologically inadequate — it used only one plant and its seeds, no control experiments were done, and the results were never confirmed.[12] Moreover, nothing in the observations repudiated classical genetic theory. Lysenko's conclusions were based not on experimental data but on deduction from a set of irrelevant *a priori* abstract ideas. Chief among these was a belief that the genetics accepted all over the rest of the world was formalistic, bourgeois and metaphysical.[13]

Later, toward the end of his reign as dictator of Soviet biology, Lysenko proposed fundamental changes in the theory of evolution. He claimed that competition does not occur between individuals of a single species in a confined environment and thus plays no role in evolution. He argued that the natural thinning out of crowded saplings in a clump occurs because some of them "sacrifice themselves for the good of the species,"[14] not because some young trees are more efficient than others in competing for a limited supply of nutrients or water. He expressed this concept not merely as a theory, but as a natural law: The Law of the Existence of a Species. He said that the law manifests itself in a species doing all it can to flourish. Again no experimental evidence was forthcoming. Lysenko found the Darwinian idea of competition within a species unacceptable not because he had facts to the contrary, but because it had roots in the reactionary writings of Malthus.[15] Lysenko legitimated his natural law by tying it to ideology.

During the same period, rigorous experiments outside the Soviet Union were consistently confirming and extending the hypotheses of classical genetics. Genes and mutations provided an explanation for the variation within species that is fundamental to Darwinian ideas. In the early 1940's, scientists discovered that each gene actually specifies one protein. In the mid 1940's, genes were identified with DNA which was already known to be a major component of chromosomes. In the 1940's and early 1950's, it was shown that DNA molecules alone carry genetic information. In 1953, Watson and Crick built a model for the structure of DNA that was consistent with the chemistry known at the time. The model inherently demonstrated how DNA can make a precise copy of itself thereby

12. *Id.* at 25.

13. For a general discussion of the ties between genetic theory and values, *see*, Graham, *Political Idealogy and Genetic Theory: Russia and Germany in the 1920's*, HASTINGS CENTER REP., October 1977, at 30.

14. MEDVEDEV, *supra* note 11, at 168.

15. *Id.* at 167.

permitting the passage of genetic information from a parent cell to two progeny cells and from a whole organism to its offspring. In the 1950's and 1960's, clean chemical experiments conducted outside a cell in a laboratory test tube showed that proteins can be synthesized using a copy of a DNA segment — that is, a copy of a gene — as a template. At about the same time, DNA molecules were synthesized by chemical procedures. And in 1961, the genetic code was deciphered when scientists determined the actual way in which DNA encodes proteins. Ironically, the first successful decoding experiments were announced by an American in Moscow at the 1961 International Congress of Biochemistry. Yet late in 1961, a Soviet biology journal stated, "The hypothetical connection of the empty abstractions [of the gene theory] with specified substrates — chromosomes, DNA — declared to be the 'material carriers of heredity' does not confer on these abstractions material content, anymore than superstitious deification of objects makes the superstitions materialistic."[16]

Lysenko was not merely engaged in an esoteric intellectual disagreement with world science. The economic consequences of Lysenko's reign were immeasurable. It is estimated that over the course of twenty years at least 30 to 50 billion kilograms of corn were lost from the mandated use of Lysenko's false principles in agriculture.[17] Hundreds of millions of rubles were wasted when Lysenko's ideas about altruistic saplings proved erroneous.[18] By denying that a virus was responsible for an international decrease in potato production he severely hampered Soviet measures to battle the disease and even caused its spread.[19] These are only a few of the economic disasters caused by the politically enforced application of Lysenko's errant theories.

Lysenko's devastation in the Soviet Union encompassed more than food production and economics; it encompassed human beings. Before he began, there were great geneticists in the Soviet Union. Their accomplishments were intellectual and practical; they excelled in the fields of agriculture and medicine. They were inte-

16. *Id.* at 146.
17. *Id.* at 181.
18. *Id.* at 168.
19. Lysenko proposed a method of summer planting of potatoes in the south of the Soviet Union in order to halt a world wide potato crop decline. The decline was due to a wide ranging virus. Lysenko, however, proposed his own explanation of the decline and proceeded to combat the disease in his own way. The result of his methods, however, was a hindrance of serious efforts to combat the virus and, by opening new growing areas, a spread of the viral disease. *Id.* at 161-163.

gral parts of the worldwide scientific community. Once Lysenko became dominant, however, they themselves, as well as their science, became officially intolerable. They were dismissed. They were publicly slandered and ridiculed. They became enemies of the people. There are many stories of courageous and patriotic individuals answering Lysenko's fantasies with sober scientific facts, unmindful that the dispute was ideological rather than scientific. Finally, there were arrests, trials and deportations to the gulag.[20] The greatest of these scientists, N. I. Vavilov, perished in prison and was mourned all over the world. He had been a great force for the modernization of Soviet agriculture and for scientific scholarship — that was the cause of his death.

As a result of Lysenko's persecutions, genetics essentially ceased to exist in the Soviet Union. Students were not educated in genetics. Whole generations of geneticists and biologists were lost. When Lysenko's reign finally ended in 1964, there were no classically trained geneticists, no genetics laboratories, nothing on which to build. Now, twenty years later, a country with a vast and productive scientific enterprise remains backward in one of the most vital of current fields, a field of extraordinary importance to both medicine and agriculture.

How did all this happen? How can it be that a scientifically progressive country with a great number of gifted, dedicated scientists fell into this costly morass? There were four reasons. First, Lysenko himself, though of doubtful educational qualifications, was an ambitious and confident man. Second, Lysenko and his followers were able to manipulate and exploit mass public communication in the service of their ideology — for example, publishing research results in simplistic form in the popular press without peer review. Third, Lysenko substituted a simple ideology and demagoguery for a complicated reality. Fourth, Lysenko received cooperation from scientifically ignorant but politically powerful accomplices, first Stalin and later Kruschev.

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20. Some of the scientists arrested for their opposition to Lysenko's views included: G.D.Karpechenko, a geneticist of world fame and leader of a school of science which solved the problem of infertility of distant hybrids; G.A.Levitsky, the leading Soviet cytologist; and L.I.Govorov, a plant breeder of leguminous seed plants. *Id.* at 70.

Other scientists opposed Lysenko by emigrating to other countries to continue their work. For example, Theodosius Dobzhansky, one of the foremost researchers in population genetics, emigrated to the United States. Graham, *supra* note 13, at 33.

III. *The Relevance for Us: Recombinant DNA*

The Lysenko story illustrates why the combination of power and scientific ignorance is so dangerous. This is not an idle, theoretical concern for us. In the United States today it is a real problem. Our country does not, of course, have an ignorant and powerful dictator like Stalin. We do, however, have a scientifically ignorant but politically powerful citizenry that can, with the proper group or individual leading the way, bring us to adopt foolish and potentially disastrous scientific policies.

One area of science in which the danger is especially evident is recombinant DNA experimentation. This technique of genetic manipulation offers the potential for immense benefits. Yet presently, recombinant DNA research is under attack on ideological grounds, an attack which poses threats to United States biological research similar to those posed for Soviet biology by Lysenko.

Recombinant DNA technology, which provides new techniques for studying genetics and manipulating genes, was developed over ten years ago. The essence of the technique is easily understood if one thinks of a gene as a piece of a DNA molecule, a chemical entity. DNA can be taken out of cells and tissues and manipulated in a test tube. It can be broken into pieces which may be joined back together again with the same DNA, or with DNA from any other living creature. Finally, these new DNA molecules can be put back in living cells, including fertilized egg cells, where they join with chromosomal DNA and become part of the permanent hereditary information of new cells or whole plants or animals.[21]

Gene cloning[22] is an amazingly productive technique for understanding living things; in the decade since its discovery, it has transformed our understanding of biological and medical science. It is also a useful technique for manufacturing biological chemicals for pharmaceutical or industrial purposes, diagnosing genetic diseases and producing vaccines. It holds great promise for the future of agriculture.

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21. For a simplified discussion of the techniques of recombinant DNA, see PRESIDENT'S COMMISSION FOR THE STUDY OF ETHICAL PROBLEMS IN MEDICINE AND BIOMEDICAL AND BEHAVIOURAL RESEARCH, SPLICING LIFE: A REPORT ON THE SOCIAL AND ETHICAL ISSUES OF GENETIC ENGINEERING WITH HUMAN BEINGS 30-36 (1982) [Hereinafter cited as SPLICING LIFE].

22. "Cloning, the production of genetically identical copies, can apply to cells or whole organisms. Although the idea of creating clones in the laboratory is new, many species of plants and animals, including humans, produce natural clones. For example, identical twins, triplets, etc., are members of a clone, since they are derived from the same fertilized egg." SPLICING LIFE, *supra* note 21, at 9 n.6.

When gene cloning techniques were first developed, members of the scientific community expressed concern that certain of these recombinant DNA experiments might result in the construction of harmful bacteria and viruses. By imposing a voluntary moratorium, the community discouraged scientists from performing the worrisome experiments until it developed a set of recommended guidelines designed to protect laboratory workers and the public should the hypothetical problems prove real.[23] Later, in 1976, the National Institutes of Health (NIH), the chief federal agency supporting biological and medical research, promulgated formal and mandatory guidelines for all experiments conducted with federal funds.[24] Scientists supported by non-federal funds continued voluntary compliance. Since 1975 the restrictions imposed by the NIH guidelines have been continually relaxed in the light of scientific data and risk assessments. At present only a very limited number of experiments are regulated.[25] The overwhelming majority of the possible hazards imagined when the methods were first developed have proven to be without substance. No hazards have resulted from the thousands of recombinant DNA experiments carried out in the last decade. In some instances the recombinant DNA approach actually lessens the hazard of investigating pathogenic agents.

If one understands biology, the fundamental aspects of recombinant DNA experiments are not at all bothersome. Most living things have tens of thousands of genes and much more DNA which serves to regulate when, where and how the information coded in the genes will actually be used. The DNA itself is not fixed in structure. It changes continually by mutation, by shuffling pieces from one place to another, by repeating segments, by deleting pieces. Addition or subtraction of a single segment of DNA, whether as a result of a wholly natural process or as a result of genetic engineering, does not make a significant difference to the identity of an organism.

If one does not understand biology, however, recombinant DNA can appear an unsettling technique. Most people do not understand that in most cases manipulation of DNA results only in a very small change in the genetic make-up of an organism; moreover, such changes rarely improve the organism's ability to live and reproduce,

23. *See, e.g.*, Berg, Baltimore, Brenner, Roblin & Singer, *Asilomar Conference on Recombinant DNA Molecules*, 188 SCIENCE 991-994 (1975).

24. 41 Fed. Reg. 27,902 (1976).

25. For a recent proposal for regulating genetic experiments, see, Office of Science and Technology Policy, Proposal for a Coordinated Framework for Regulation of Biotechnology, 49 Fed. Reg. 50,855 (1984) (proposed December 31, 1984).

except under special laboratory conditions. Instead, many people believe incorrectly that genetic engineering is geared toward the production of new science fiction-like species or organisms, a feat that is essentially inconceivable. Beginning in the mid 1970's, the disquiet stirred by such beliefs became the basis for continual questioning of the many facets of genetic engineering. Some of this questioning has been reasoned and productive.[26] Some of it, however, has been based on erroneous assumptions about biology and the significance of the experiments performed. This contentious atmosphere was exacerbated by misleading statements that the debate was closed to the public; in fact, the development of the NIH guidelines was a completely public undertaking. In recent years these erroneous assumptions and misleading statements, couched in an ideological framework, have, to a large extent, emanated from one person, a skilled Washington lobbyist, publicist and writer, Jeremy Rifkin.

The tone of Mr. Rifkin's rhetoric was established publicly in 1977 when he disrupted a planned open forum on recombinant DNA experiments at the National Academy of Sciences in Washington, D.C.. After threatening to close the forum down by disruption, Mr. Rifkin was given the opportunity to speak and to organize demonstrations in the hall. He said:

> My friends, the real issue is not whether the laboratory conditions are safe or unsafe [which was actually the issue on the agenda]. . . .The real issue here is the most important one that human kind has ever grappled with. . . .It is now only a matter of time, five years, fifteen years, twenty-five years, thirty years until biologists . . . will be able literally, through recombinant DNA research, to create new plants, new strains of animals and even genetically alter the human being. . . .The American public does not know anything about this issue yet.[27]

Of course, by 1977 it had been several thousand years since human beings had begun to alter the genetic make-up of plants and animals by manipulating genes through selective breeding. Also by 1977, for the four years since genetic engineering experiments first became feasible, the public had been informed by scientists, the printed press and television. The issue was broadly, even vehemently, discussed.

In 1983, Mr. Rifkin continued his campaign in a theological letter

26. *See, e.g.*, SPLICING LIFE, *supra* note 21, at 10-17.

27. NATIONAL ACADEMY OF SCIENCES, RESEARCH WITH RECOMBINANT DNA, AN ACADEMY FORUM 19-20 (1977).

which outlined his moral arguments against genetic engineering of human germ line cells.[28] It called for a prohibition on genetic engineering of the germ line of the human species. The letter claimed that it would soon be possible to engineer and produce human beings by the same technological design principles currently employed in industrial processes.[29] Such a statement is science fiction. It displays an ignorance of both what is known and what is not known about human organisms. In Mr. Rifkin's sense, we cannot now produce human beings, and it is unlikely to be possible in the foreseeable future.

Germ line manipulation is proceeding with mammals other than humans. Mice are the favored experimental animals and the methods are now being extended to agriculturally important species such as cows. With mammals, a single gene or DNA fragment isolated by recombinant DNA techniques is injected into very early embryos which are then implanted into the uterus of females. Some of the animals which are eventually born contain, in addition to their full normal set of DNA, one or more copies of the new gene. These may or may not be functional, but they are heritable in future generations. The first such experiments were reported a few years ago. In one, the human gene for growth hormone was inserted into mice, yielding some larger than normal mice. The technique provides a remarkable opportunity to learn about gene expression and regulation, fetal development and the causes of tumors. It also offers an opportunity for substantial improvements in food production — an opportunity with both humanitarian and economic advantage. These experiments are also preliminary requirements for any future efforts to correct human genetic defects by modification of germ lines.

Animals modified with germ line techniques are termed transgenic and, along with similarly modified plants, are the target of Mr. Rifkin's most recent campaign. The campaign against transgenic experiments has been two-pronged. First, Mr. Rifkin's organization, The Foundation on Economic Trends, filed suit to enjoin the Department of Agriculture from proceeding with its support for experiments designed to place the human growth hormone gene into animals used for food. The experiment was designed to determine

28. J. Rifkin, The Theological Letter Concerning the Moral Arguments against Genetic Engineering of the Human Germline Cells (1983) (letter accompanying press release of June 8, 1983) (on file with *Yale Law and Policy Rev.*) [hereinafter cited as Theological Letter].

29. *Id.*

whether the efficiency of meat production could be improved. Moreover, the human gene had been specifically chosen because it had already been isolated by recombinant DNA techniques, was readily available, and had previously been tested in the successful experiments on mice. Nevertheless, Mr. Rifkin wants to ban these experiments. His motivation is made clear by his second offensive, a proposal for sweeping modifications of the NIH's Guidelines for Recombinant DNA Research[30] — the rules that are designed to ensure safe practices for experiments that may have some probability of producing hazardous agents. Mr. Rifkin wants to prohibit *any* experimentation involving the transfer of a genetic trait from one mammalian species into the germ line of another unrelated mammalian species, including human genes and organisms.[31] His proposal further suggests that consideration be given to extending the prohibition to all species, presumably including plants. The reason given is that such experiments are a gross and unconscionable violation of the "telos" of each species and are, as such, morally reprehensible.

In Greek "telos" means "end." In English, it carries the additional connotation of purpose, of ultimate aim. Mr. Rifkin's argument then sounds much like Lysenko's "law of the existence of a species." The idea that a species has a "telos," a purpose, however, still contravenes everything we know about biology, just as it did in Lysenko's time. The only end that is demonstrable for a species is its extinction; many species have become extinct in the past, and others will do so in the future. Moreover, individuals within a species do not have identical DNA; DNA molecules are not fixed and frozen, but rather continually change as organisms evolve. DNA within cells is not inviolate; for example, within the DNA of many organisms is found DNA from separate entities, viruses, which inserted itself either generations ago or during a more recent infection. What then is the "telos" that is to be preserved? It is nothing but a mystical concept, raised in opposition to scientific fact in Mr. Rifkin's attempt to end genetic experimentation.

In ignoring scientific facts in favor of ideology, Mr. Rifkin's rhetoric shifts public debate away from those aspects of recombinant DNA experiments which do raise serious questions. In his theological letter, Mr. Rifkin asks "What is the price we pay for embarking on a course whose final goal is the 'perfection' of the human spe-

30. 49 Fed. Reg. 46,266 (1984).
31. *See generally* J. RIFKIN, ALGENY 232-233 (1983).

cies? Who do we designate to play God?"[32] The answers to these questions are straightforward. Biologists have not embarked on a course to perfect anything; the concept of perfecting living organisms is a contradiction of everything we understand about biology. No one will ever play God. If one day parents have the chance to replace a defective gene such as that causing hemophilia ,sickle cell anemia or Tay Sachs disease in their hoped for offspring, they will not be playing God. They will be working hard at one of the most serious problems that parental responsibility can carry.

It is important here to recognize that the therapeutic replacement of faulty genes is quite a different matter from the science fiction notion of assembly line production of human beings. Moreover, it is necessary for both scientific and philosophical reasons to distinguish two kinds of gene replacement. One proposes to replace or add genes in whole, free living organisms and is called somatic gene therapy. This technique is likely to be a reality in the near future. The second kind proposes to replace or add genes to eggs that will then develop into whole, free living organisms and is called germ-line manipulation. A critical difference between them is that changes made in germ-line manipulation will be passed on to future generations while somatic changes are lost when the recipient individual dies.

The consequences of the capability of manipulating human genes present an important issue which deserves continual and serious thought. At the time of Mr. Rifkin's letter, scientists and physicians had already begun to consider the implications of both somatic and germ-line manipulation of human genes. Most had concluded that altering *human* germ lines should not now be undertaken but that somatic therapy presents few unique ethical questions. Thoughtful citizens had also begun to consider the issues. A Presidential Commission had already published an extensive and reasoned report concluding that the issues deserved continual public scrutiny as the capability to modify human germ line DNA approached.[33] The Presidential Commission itself was prompted by a letter to President Carter in July, 1980, from Jewish, Catholic and Protestant associations. The Commission solicited detailed views from both religious organizations and a broad spectrum of citizens. The report was the subject of extensive Congressional hearings.[34] Unlike the theologi-

32. Theological Letter, *supra* note 28.
33. SPLICING LIFE, *supra* note 21, at 81-88.
34. *See, e.g.*, HUMAN GENETIC ENGINEERING: HEARINGS BEFORE THE SUBCOMM. ON IN-

cal letter, however, neither the report nor the Congress recommended banning anything.

A piece of DNA, a gene, cannot be discussed as an abstract entity. It is a molecule whose precise structure can be sufficiently well defined that it can be made in a test tube using chemical procedures. Human growth hormone gene, as well as other genes, can be made by purely synthetic procedures in a laboratory. Would the insertion of the synthetic gene into a laboratory mouse be morally reprehensible? These synthetic genes have the same structures as those obtained by recombinant DNA techniques that start with DNA isolated from human cells. The human genes now being inserted into the eggs of other mammals were never in a human either; they are synthesized in bacteria using a recombinant DNA form of the human gene as a template. Moreover, no single gene determines that an organism is human. No single gene makes a mouse distinct from a rat. Species differences may or may not be fully accounted for by genes alone — other segments of DNA that regulate how and when genes work may well prove more important. A living organism is the result of an extraordinarily complex interplay of thousands of genes and thousands of products of gene expression.

In view of these facts about biology and genetic engineering, Mr. Rifkin's arguments become a pointless divergence. The report of the President's Commission speaks to this issue:

> In the absence of specific religious prohibitions, either revealed or derived by rational argument from religious premises, it is difficult to see why 'breaching species barriers' as such is irreligious or otherwise objectionable. In fact, the very notion that these are barriers that must be breached prejudges the issue. The question is simply whether there is something intrinsically wrong with intentionally crossing species lines. Once the question is posed in this way the answer must be negative — unless one is willing to condemn the production of tangelos by hybridizing tangerines and grapefruits or the production of mules by the mating of asses with horses.[35]

Rather than focusing on ideology, scientists and citizens should focus on the real problems of helping the victims of genetic disease and improving agricultural productivity.

Another misguided attempt to shift the focus of public debate away from fact and into ideology is found in Mr. Rifkin's effort to stop a recombinant DNA experiment by raising the question of bio-

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VESTIGATIONS AND OVERSIGHT OF THE HOUSE COMM. ON SCIENCE AND TECHNOLOGY, 97th Cong., 2d Sess. (1982).

35. SPLICING LIFE, *supra* note 21, at 57.

logical warfare. His specific aim was to stop experiments designed to isolate a gene encoding a bacterial toxin, the Shiga toxin. This toxin, when produced by certain bacteria that also show other traits, produces dysentery in man. The aim of the experiment was to study the toxin and to develop vaccines not only against the shigella organism, but also against cholera.

An official review by the NIH and its oversight committee for recombinant DNA experiments concluded that the experiments could be carried out safely under rigorous containment.[36] The expert investigators who proposed the experiments, however, happened to be on the faculty of the medical school run by the Department of Defense (DOD). The implication of Mr. Rifkin's public statement was that since the work was to be conducted within DOD, the arms control and disarmament impact of the work needed formal assessment. The DOD's medical school is, however, like any other medical school, a place where research is done openly. It is not a military installation. The work in question was not even to be funded by DOD but rather by NIH. The intentions of the investigators were scientific and humanitarian. Moreover, Mr. Rifkin's scenario depicting the potential misuse of the gene or vaccine was simplistic and unrealistic. This is not to say that we ought not worry about the real implications of genetic engineering for biological warfare agents. We should. But the facts of the Shiga case clearly show that potential misuse in biological warfare was not a significant issue here. Once again, by focusing on a tangential ideological issue, Mr. Rifkin detracted both from the more important issue of the safety of the Shiga experiment itself and from future serious consideration of the potential of genetic engineering for creating agents of biological warfare.

In Mr. Rifkin's statements, as in Lysenko's, there is a lack of precision and rigor in describing scientific theories and disputes; a confusion of context; and a misunderstanding of the nature of scientific process, of the body of scientific facts and of the extent to which this body is incomplete. Nevertheless, Mr. Rifkin's statements, again like those of Lysenko, are readily accepted by those with the power to pursue them. Though it distorted scientific knowledge and ignored past scientific and public debate, Mr. Rifkin's theological letter was signed by approximately fifty religious leaders of various denominations. Some of the signatories later tried to dissociate themselves from the letter, explaining that they sought only to en-

36. 48 Fed. Reg. 1156 (1983).

courage discussion. Did they read what they signed? One must assume so. But could they understand it? The fact that they so quickly changed their position suggests that these clergymen, leaders in our society, were ignorant of the scientific factors which should have weighed in their original decision, choosing instead to sign on the basis of ideological rhetoric. Similarly, with respect to the Shiga experiment, Mr. Rifkin recruited several distinguished experts on nuclear weapons control to sign a statement opposing the experiment. The facts in that case clearly showed that a potential for biological warfare was simply not a significant issue. Again, individuals who are expected to be informed leaders, arms control experts, ignored scientific fact in favor of Mr. Rifkin's simplistic rhetoric.

Mr. Rifkin has also found an ally in the courts. In September of 1983, he and his organization, the Foundation on Economic Trends, brought suit to enjoin a plan by scientists at the University of California to field test, on a small potato patch, a genetically engineered bacteria. The parent bacteria encodes a protein that facilitates frost formation. The bacteria is commonly found in potato fields in northern California where it can damage crops when the temperature drops close to freezing. If the wild bacteria could be replaced by a mutant bacteria that no longer produced the protein, then potato crops might be safe for a few extra degrees of temperature drop.

Prior to the proposed experiment, such mutant bacteria had, in fact, been isolated by standard, old-fashioned genetic techniques. In field tests, these bacteria survived without the protein, though not very well, and some plant protection occurred. Since mutants obtained by classical techniques frequently revert to wild type, however, better results would be obtained with engineered bacteria entirely lacking the wild type gene. Such were the bacteria which were to be tested.

The prior experiments with natural mutants provide a highly pertinent assessment of the risk of unexpected negative consequences — none were found. Bacterial strains with a mutation in the protein gene do not spread; they do not compete well with the strains normally found in nature. In short, the proposed experiment was highly unlikely to affect the environment outside of the potato patch. Rigorous scrutiny by the NIH advisory committee charged with oversight of recombinant DNA experiments reached this same conclusion; the committee recommended proceeding. Neverthe-

less, in a decision quoted earlier, the experiment was enjoined by the D.C. District Court.[37]

In halting the experiment, Judge Sirica agreed with Mr. Rifkin's charge that there had been a failure by the NIH to comply with the National Environmental Policy Act[38], because no formal Environmental Impact Statement had been prepared.[39] An Environmental Impact Statement is required by the law prior to final approval of all "major Federal actions significantly affecting the quality of the human environment."[40] As I have already pointed out, however, there was no reason whatever to believe that the proposed field test would affect the human environment at all, let alone significantly. Moreover, it is difficult to think that seeding a tiny potato patch with a relatively incompetent variant of a common bacteria is a major federal action. The plaintiff's arguments that were accepted by Judge Sirica may make sense from a narrow legal perspective, but they make little sense in the context of available scientific knowledge. I cannot help but wonder whether the case might not have been found frivolous to begin with, if the Judge had understood the science. As he admitted in his decision, however, "this Court is not, and does not purport to be, competent to address the host of scientific issues associated with the use of the recombinant DNA."[41] This ignorance troubled the Judge not at all. He simply accepted it; with it, he accepted the plaintiff's definition of the problem framed in terms of ideology.

Since 1977, Mr. Rifkin has again and again opposed modern genetic research. Examining his claims, we see that his attacks are not rooted in a concern for the advancement of religious principles, the protection of the environment, or the prevention of biological warfare. These are simply popular causes to which Mr. Rifkin has connected himself when convenient to the achievement of his actual objective. Mr. Rifkin fundamentally objects to the manipulation of DNA. His objections distort scientific fact in favor of a "mystical personal philosophy and apoocalyptic vision."[42] They ignore extensive public debate which addresses many of the actual problems in-

37. FET v. Heckler, 587 F.Supp. 753 (D.D.C. 1984), *aff'd*, 756 F.2d 143 (D.C. Cir. 1985).

38. National Environmental Policy Act of 1969, 42 U.S.C. §§4321-4370a (1982).

39. FET v. Heckler, 587 F.Supp. at 761-764.

40. National Environmental Policy Act of 1969, §102(2)(c), 42 U.S.C. §4332 (2)(c) (1982).

41. FET v. Heckler, 587 F.Supp. at 755.

42. Davis, *Judge Sirica Chills Genetic Research*, Wall St. J., July 13, 1984, at 18, col. 4.

herent in such manipulation. Nevertheless, his objections are listened to by many who have the power to implement them.

The policies established by T.D. Lysenko had disastrous results. Economically and scientifically they severely disadvantaged the Soviet Union. The policies which follow from Mr. Rifkin's rhetoric pose similar threats. Yet today, in the United States, the scientific ignorance of policy-makers — legislators, clergymen, arms control experts, judges — is resulting in a pointless slowing of scientific work and could result in the further implementation of these very policies. To resist their pull, rooted in the attraction of a simplistic ideology, a truly informed citizenry will need to understand science. The gap between science and law which allows demagogues such as Lysenko and Rifkin to manipulate science by playing on people's ignorance must be bridged.

IV. *Bridging the Gap*

In 1959, Snow laid the blame for the devastating separation of science and law on the educational process.[43] The same is true today. In the United States, schools are supposed to make studies attractive and to encourage students in their progress. When it comes to science (including mathematics), however, this rarely happens. Instead of receiving encouragement, a large number of very intelligent young people come away convinced by the schools that the natural world is a boring and impenetrable place.

Snow recognized that one feature of the scientific culture is optimism. In that tradition, I will make a suggestion for beginning to bridge the gap between science and law. I focus on law both because of the audience and because of the power of the legal community in our society. My proposal is only a beginning on the path to the real goal, the scientific education of the entire citizenry. Taking note that the definition of the qualities which make a good lawyer has changed before and can change again, I suggest that lawyers be required to display a basic knowledge of biology and other sciences. Practically, this might be achieved if a set of questions concerning science appeared on the LSAT's.

I anticipate more than a little trouble convincing those who matter that this is a good idea. The most striking peculiarity of the LSAT's is the absence of substantive questions of any kind, let alone scientific ones. It appears that knowledge is irrelevant to the selec-

43. SNOW, *supra* note 2, at 19-22.

tion of candidates for law school. The LSAT samples I have read test only a talent for the manipulation of closed sets of statements. Thus, before trying to convince the arbiters of law school admissions that science is important to the study of law, I would have to convince them that any substantive knowledge at all is important.

To maintain some sort of congruence between public policy and justice on one hand and reality on the other, a lawyer surely should know a great deal beside the law. I put knowledge of biology and genetics first because they speak to the fundamental nature of human beings and because they have recently changed to become manipulative sciences. Their potential for good and for evil is large. Societal evaluation of their effects, which in our country means legislative or judicial review, is bound to be unwise, even tragic, unless it is based on facts rather than fantasies.

I return finally to Lord Snow. In 1959 he closed his book with this:

> There are steps to be taken which aren't outside the powers of reflective people. Education is not the total solution to this problem: but without education the West cannot even begin to cope . . . Closing the gap between our cultures is a necessity in the most abstract intellectual sense, as well as in the most practical . . . Isn't it time we began?[44]

Today, in the United States, the threat which results from the scientific ignorance of policy-makers must be faced. Genetic engineering is only one area of science in which this ignorance can lead to disastrous results. Education can end this ignorance. Education might have prevented the rise of Lysenko, and it can prevent the unquestioning acceptance of Mr. Rifkin's mysticism. As in Snow's time, education is the solution. Is it not time we began?

44. *Id.* at 53-54.