Biology and Society—1820, 1998, and Beyond

Christopher DeMuth, at the Business Council of Williamsburg, Virginia

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To grasp the importance of developments in genetics and biotechnology in the year 1998, one really must go back to the year 1820. The recent defeat of Napoleon's Evil Empire had ended a half-century of continuous war and revolution, releasing vast, pent-up social energies for science, commerce, art, and literature. Yet the one remaining superpower, Great Britain, seemed consumed by a sensational sex scandal at the heart of the government. Queen Caroline, wife of the new King George IV, was a woman with a past, and also a present. A team of special government investigators had compiled comprehensive evidence of her adulteries and delivered it to the House of Lords, which began proceedings to strip her of her queenship. The lurid details of the Queen's assignations shocked even the most cosmopolitan, and presented embarrassing challenges to newspaper editors, hostesses of dinner parties, and parents of young children throughout the realm. Yet the nation was deeply divided over what, if anything, ought to be done, and the pro-Queen and anti-Queen forces reflected partisan political divisions as much as disagreements about sex and lying. One contemporary wrote that "I never remember any question which so exclusively occupied everybody's attention and so completely absorbed men's thoughts and engrossed conversation."

But not everybody's thoughts and attention. For in that same year of 1820 John Dalton delivered his landmark "Memoir on Oil, and the Gases Obtained from it by Heat," the scientific origin of the modern oil and petrochemical industries; papers by Orsted and Ampère described an amazing relationship between magnetism and electricity, propelling Michael Faraday on his quest for machines to generate electrical energy from physical motion and vice versa; and Charles Lyell began his first work on geology, which, by treating the origin and history of the earth as natural and continuously changing rather than supernatural and fixed, was to inspire the lifework of his friend Charles Darwin.

By year's end the British public had wearied of the Queen Caroline scandal and wished that it would go away and the Queen with it; the proceedings in the Lords were soon abandoned amid bitter political recriminations, and within a year the Queen herself was dead. But in a decade Faraday had bequeathed the world his electric dynamo and Darwin was embarked on HMS Beagle on the most consequential voyage in the history of mankind. The quiet scientific advances of that tumultuous year lived and grew and transformed the world.

The events of 1820 mark the beginning of the modern age—the age when science and industry have displaced politics as the driving force of social and economic development. Great men and scoundrels continued to devote themselves to politics, terrible wars were fought, governments grew bigger and busier than they had ever been before—yet the society we know today was made by the wholly unprecedented and mostly private and apolitical progress of our knowledge of the natural world and the rapid commercial deployment of that knowledge.

Many of the great technological feats of those 178 years—in energy, construction, transportation, and communications—have dramatically changed our physical environment and the ways we live and work and spend our time. But it has been advances in biology and in the health and agricultural sciences that have had the most profound effects on human welfare and social structure. Improvements in diet and medicine have made men and women far taller, stronger, healthier, and longer-lived than ever before—a transformation of the species far beyond any change discernible in the previous 11,000 years following the discovery of agriculture. In an era when social equality has become a central political concern, improvements in public health have done more to equalize real life circumstances than any government policy. In 1820 the typical adult male worker in Britain was five inches shorter than his upper-class countryman; today the difference is about one inch. As recently as 1870 the average lifespan of the British upper class was more than seventeen years longer than that of the population as a whole; today the difference between the richest and poorest Brits is less than two years.

These historic reductions in social inequality came about mainly in the twentieth century—indeed they appear to have worsened during much of the period of rapid industrialization of the nineteenth century. What turned the tide were huge investments in biomedical technology and clinical medicine, cleaner public water and sanitation, and cleaner, cheaper, and more nutritious supplies of basic foods—all yielding relatively greater benefits for the poor than for the well-to-do. A powerful secondary effect of improved medical care and farm production was to launch women on the path toward social equality, a trend augmented in recent decades by the growth of the service and white-collar sectors: over the past century women's wages have risen on average 50 percent more rapidly than those of men. During the past third of a century, the development of cheap and effective contraception has probably had a more profound effect on social mores and family structure than any other technological advance, television and the automobile included.

These examples illustrate that achievements in the biologic sciences have yielded not only tremendous improvements in material welfare but also momentous changes in social relations and ethical norms. It is important to understand the range of consequences, because our knowledge and mastery of nature seems now to have entered an entirely new and more powerful phase. Beginning with Watson and Crick's identification of the basic architecture of DNA in 1953, and especially since the development of recombinant DNA techniques starting in 1973, a cascade of astounding discoveries concerning the mechanics of genes and their complex interaction within living organisms, and inventions for the direct manipulation and duplication of genes, justify the prediction that we are entering an "age of biogenetics."

The popular press and business press have placed heavy emphasis on imminent commercial applications of genetics and biotechnology; just now investors appear a bit cooler on medical and pharmaceutical applications, and warmer on agricultural applications, than they were a few years ago. No matter. The great medical advances of this century, as Lewis Thomas pointed out some years ago, have come not from applied but from basic research—that is, from new knowledge of underlying biological mechanisms—and in genetics our understanding of underlying mechanisms is increasing exponentially with no end in sight. One byproduct of the growth of basic science is that we can now say with virtual certainty that a given set of technical problems will be solved, long before we know exactly how they will be solved—just as NASA engineers were confident that they could land a man on the moon several years before they knew how they would do it, and as today the wizards at Intel are confident that they will continue to increase microprocessor speeds at rates comparable to those of the recent past.

So although geneticists and biotechnologists cannot say exactly how they will do it, and although there will be many flops and lucky breaks along the way, they know for certain today that they are going to bring many miracles to pass in the coming decades. I will mention six practical developments—three in food and agriculture and three in human medicine and biology—that are highly likely and in some cases well underway. And I will suggest a few possible social consequences of these developments.

Development 1. Agricultural yields, both of plants and livestock, will increase greatly, due to genetic engineering of reproduction and growth and of resistance to pests, disease, and weather.

Some consequences. As food continues to become cheaper and more plentiful, famine, malnutrition, and hunger will become, even more than they are today, purely political and economic phenomena—not to be explained away or tolerated as the inevitable result of too little supply or too many mouths. The first nations to accept the widespread introduction of genetically engineered foods will be the United States and Bangladesh; the last will be Germany and France.

Development 2. Foods will be genetically designed not only to improve nutritional properties but to combine them with medicinal properties, including the reduction of risk of specific diseases.

Some consequences. The link between diet and health, including disposition to disease, will come to be much more generally recognized than it is today—but poor eating habits and increased government regulation of "nutraceutical" foods *will eliminate some of the potential health benefits of better foods and increased public awareness.*

Development 3. Genetic engineering of plants will yield effective substitutes for many critical materials such as plastics and metals that are now derived from petroleum and other minerals.

Some consequences. The substitution of renewable resources for nonrenewable resources will alleviate many serious environmental problems—but leading environmental groups will be as divided as the Business Council over the desirability of these changes. Tax provisions will be enacted to subsidize certain renewable substitutes—but they will back the wrong technologies.

Development 4. Genetic diagnostics will improve dramatically, making the medical diagnosis of patients' symptoms much faster and surer and also permitting much more precise identification of individuals who are predisposed to certain diseases.

Some consequences. Genetic diagnostics will permit great improvements in the efficacy of medical treatment and also in the management of health care—from the design of insurance to the introduction of new forms of specialty treatment centers. But progress in diagnostics will also prompt great political controversy—legislation will be introduced to ban "genetic discrimination" by employers and health insurers and to enact a "right of privacy" to one's own genetic information.

Development 5. The advance of genetics and biotechnology will produce historic breakthroughs in the medical treatment of inherited and acquired diseases, burns and other traumas, birth defects—and even baldness. The medical response to dread diseases, including many forms of cancer, AIDS, and Alzheimer's, will progress from treatment, to cure, to prevention. Medical intervention will progress to pharmaceuticals that are custom tailored to the genetic profile of individual patients, and to "gene therapy"—direct genetic alteration of the cells of living organs to supercharge their response to disease, infection, and trauma. And someday, somewhere, gene therapy will move to "germ-line therapy"—the now-taboo genetic alteration of sex cells to affect the attributes of an individual's progeny and successive generations, for example in the disposition to certain inherited diseases.

Some consequences. These are the Holy Grails of genetic research; their social consequences will be extensive. First and foremost will be immense reductions in human pain and suffering and increases in health and longevity. Healthy and active people in their eighties and nineties will become commonplace. Pundits will assert that these blessings are really a curse—bringing ruinously high health care expenditures and Medicare and Social Security bankruptcy—but they will be mistaken. The problems ascribed to better health and longer lives will really result from outmoded government financing arrangements, and these will be *promptly reformed along lines proposed by the American Enterprise Institute. But serious new social challenges and ethical dilemmas will indeed arise: an older society may be more stable but also more stodgy and risk averse; ameliorating the biologic causes of disease will lay bare the role of their social and behavioral causes, intensifying debate over many sensitive and uncomfortable subjects; germ-line therapy will present monstrous as well as benign eugenic possibilities.*

Development 6. Finally, animal cloning will progress all the way up the mammalian tree. Laboratory and domestic animals will be successfully cloned, then commercial livestock, then endangered species, then man himself.

Some consequences. Popular opposition to animal cloning will evaporate when the Bengal tiger is cloned, then maybe even the spotted owl and the snail darter—but environmental groups will once again be conflicted by the prospect of technology-driven success. Human cloning will first be justified by, and limited to, infertile married couples, extending their options for children beyond the current ones of adoption, artificial insemination, and surrogate motherhood. No one knows how many couples will prefer a clone of one parent to a natural child of one parent and an unknown mate or to an adopted child. And no one knows what will be the nature and extent of the demand for individual cloning, the ethical issues raised by extramarital cloning, or the social consequences of the introduction of asexual human reproduction.

Developments such as these suggest that history may view 1998 as a reprise of 1820. But the growing social importance of science has become so pronounced that even Washington has noticed. In the past fortnight, the Beltway's two leading political journals, the liberal New Republic and the conservative Weekly Standard, have both interrupted their energetic coverage of the Clinton-Lewinsky affair for major essays on science and society. The New Republic's is titled "The Big Bang, DNA, and the Rediscovery of Purpose in the Modern World"; the Weekly Standard's begins with the proposition that 1998 may be remembered as much for discoveries about animal cloning as for discoveries about sex in the Oval Office.

In fact, governmental interest in science and technology is nothing new. For more than a century, every large-scale technological development has sooner or later attracted the attention of ambitious politicians who have sought to take credit for its social benefits, mitigate its social costs, and harness it for political purposes. This was true of the railroads and airlines; of electric power, telephony, and radio and television; of Standard Oil; of pharmaceuticals; of the automobile. Washington has recently, and rather abruptly following years of neglect, become keenly interested in computers and information technology, launching antitrust suits, special taxes and subsidies, encryption protocols, export restrictions, and other projects for putting government in the driver's seat on the "information superhighway." There is no reason to suppose that biotechnology will be exempt from similar attentions.

So far, government regulation of biotechnology has been relatively benign and unintrusive. In the 1970s, fears that recombinant DNA research in university laboratories might unleash deadly mutant bugs on the general public were calmed by sensible, temporary research protocols administered by the National Institutes of Health. A subsequent effort by the Environmental Protection Agency and the Food and Drug Administration to erect a special, comprehensive regulatory edifice over biotechnology was quashed during the Reagan and Bush administrations; controls under existing statutes came down hard for a while on such things as field testing of bioengineered plants, but these have since been relaxed. The good political reputation of the biotechnology industry has been a force for moderation and reform of the FDA's severe overregulation of new pharmaceuticals.
But this situation may change as genetics and biotechnology progress beyond the laboratory and the manufacture of foods and pharmaceuticals— and as the exigent public issues move from the familiar ones of safety and environmental side effects to the unsettling economic and ethical consequences of intended uses. The coming controversies that I alluded to in my examples arise mainly from two circumstances.

First, the government is already heavily involved not just in the funding of biomedical research but in the regulation and direct financing of medical care and old-age income, generally through insurance programs that are poorly designed for contemporary demographic circumstances and that are already in serious trouble. In the 1980s the Office of Management and Budget was seriously concerned about the implications of bovine growth hormone for federal expenditures on the milk price-support program. The abolition of the farm subsidy programs is now well underway and probably means that progress in agricultural biotechnology will proceed relatively unimpeded. But the organization, financing, and provision of medical care are now a major, and evidently a durable, part of our government and politics. The deployment of every miraculous new pain-relieving, disease-curing, life-improving, and life-lengthening medical advance will be affected and in many cases afflicted by the decisions of large government bureaucracies with interests of their own.

Second, the progress of genetic research is presenting humankind for the first time with true and detailed knowledge of the material essence of life itself. The power for good and evil bestowed by this knowledge presents ethical dilemmas more profound than anything encountered since the Garden of Eden, involving issues of family, sex, reproduction, abortion, and euthanasia that are already the most vexing and contentious of the age. The congressional debates during the past eighteen months over President Clinton's proposed ban on human cloning, raising concerns ranging from fetal tissue research to freedom of scientific inquiry, hint of what is to come.

There are three rules of engagement for scientists, engineers, and business executives who will be navigating across this uncharted territory. The first is to avoid overpromising and speculating and to focus heavily on realized achievements and their practical benefits—in other words, to learn from the many mistakes of the advocates of nuclear power when they were still wearing white hats in the 1950s and 1960s. The second is to appreciate that science, while still the most prestigious institution in American society, is no longer so dominant that its advocates can avoid engaging, learning from, and compromising with people of different religious or ethical viewpoints. The third is to appreciate that the improvement of health and well-being, the relief of pain and suffering, and the extension of man's dominion over the earth are themselves ethical imperatives of the first order, and that men of science and commerce have the singular responsibility to advance them vigorously in public debate.

The most hopeful augury for the coming debates is that I didn't make up these rules myself, but rather learned them from listening to the front-line leaders in the new age of biogenetics, several of whom are with us this morning and from whom we are about to hear.