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Introduction

The capacity to manipulate the genetic templates that shape all living beings was long the plaything of science fiction. That humans could mold the biological determinants of their own character was eerie and unreal. But then, in the final decades of the twentieth century, intellectual alchemy transmuted genetic tinkering from dream into reality. In 1953 two young scientists identified the double helix, composed of four nucleotides, containing the code of all life. In so doing they opened the first chapter in the saga of molecular biology. In 2001 two scientific teams, competing to read the components of the human genome, wrote another chapter. But these events are the barest beginnings of the gradually emerging understanding of the forces that shape humans, that cause them to sicken, and that eventually cause them to die.

Commentators still remain free to imagine futures as they will, much as observers of the first steps of industrialization saw quite different worlds emerging from the new machines. Some looked at machines and saw dehumanization and the demise of skills. Others looked and saw abundance and leisure. What none could fully apprehend was that the vision of people who lived with the new technology would be fundamentally and irreversibly different from that of people who only imagined what the future might hold.

Those alive after the advent of electricity, mass production, modern telecommunications, air travel, and computer science have been shaped by those technologies in ways that those born in earlier times could not imagine. Not even the cleverest person in 1800 could fathom the effects of these future technologies, not least because they could not even imagine what all of those technologies would be. Nor, perforce, could they see the future through eyes of those who would be alive to experience the as-yet-undiscovered technologies.

The molecular biology century, as the twenty-first century may well be called, will almost certainly change how humans see the world and themselves. Even if an eighteenth-century artisan who had cried jeremiads against the dehumanization of machine production was somehow teleported into the present and said, See, I told you so, we would not take such testimony seriously. Such criticism would be pointless—quaint and irrelevant commentary from inhabitants of a world now as imaginary to us as ours was to them. For these reasons, those who pass moral judgment on the new world to which revolutionary advances in molecular biology will give birth are engaging in a kind of romantic irrelevance—attempting to apply early-twenty-first-century standards to a future world as different from our own as ours is from the artisanal life of the eighteenth century.

We present the following essays in that spirit. We are persuaded that molecular biology will alter human lives and consciousness at least as profoundly as did the industrial revolution, modern telecommunications, mechanized travel, and the information revolution. Side by side with these developments came improvements in public health, nutrition, and medical treatment. Birth rates plummeted. Life expectancies soared. And the content of lives changed.

No one can predict the precise extent or timing of advances in molecular biology. No one can foresee when particular diseases will be prevented or cured. No one can know exactly when or even if human aging will be slowed or stopped. No one yet knows for sure whether the genetic makeup of humans limits life span or, if it does, what those limits might be. Some families include more nonagenerians and centenarians than any roll of nature's dice can explain. This fact suggests that genetic inheritance powerfully influences longevity. Average human life spans longer than any nation's current average may be achievable without genetic tinkering. Even if life span now has limits, molecular biology may reveal that these limits are variables, not constants, and provide ways to slow aging and to prevent or cure illnesses that cause physical decline and death.

The Frontiers of Molecular Medicine

John T. Potts and William B. Schwartz open this volume by describing the channels through which such advances could occur. Humans have been trying to cure their own diseases for millennia. Potts and Schwartz make clear that scientific advance has revolutionized the assault on human illness. Current methods flow directly from the emergence of a detailed understanding of the functioning of human cells and an emerging understanding of the structure and function of human genes and their protein products.

Physicians have long understood, in some sense, the basis of successful medical treatments. Still, the underlying processes by which these interventions worked their magic remained hidden. The first antibiotics, for example, were more or less serendipitous discoveries. The death of bacteria led an astute observer to recognize the potential value of a mold as a source of penicillin for the treatment of infection. Later antibiotics resulted from systematic searches. But the fundamental reasons why antibiotics killed pathogens for decades remained as mysterious to the discoverers and to the physicians who used the drugs as they were to the patients whose lives they saved.

Safe correction of genetic defects through insertion of normal genes into the patient's DNA (dioxyribonucleic acid) seems to be an ever-retreating target. The more promising near-term approach is likely to be through identifying the pathologic proteins specified by an abnormal gene and synthesizing a drug that can offset its effects. Whether progress will be fast or slow cannot be forecast because this new field—structural genomics—must surmount major obstacles before it yields effective therapeutic agents. But expectations are high that intense research—by government-supported scientists and by drug companies with dollar signs dancing before their eyes—will lead to a wide range of breakthrough agents. Portents for the discovery of cures for major diseases within the first half of the twenty-first century are extremely encouraging. If each disease resulted from a single genetic defect, progress could be extremely rapid. Unfortunately, only a few illnesses are directly traceable to a single genetic flaw. Most illnesses result from multiple genetic mutations and the expression of a vast number of proteins. This painful reality guarantees that major resources over many decades will be required to produce the promised cornucopia of new drugs.

Potts and Schwartz provide a *tour d'horizon* of the multiple frontiers of biomedical advance. No brief chapter can encompass the enormous range of current biomedical research. Nonetheless, their chapter identifies a variety of fields in which progress is particularly encouraging. For example, molecular biology has created a whole new field of therapy: regenerative medicine. Skin, tissue, and whole organs may be grown in the laboratory and implanted in living humans to repair injuries and replace worn-out body components. Organs may soon be grown in animals that have been biologically modified so that human recipients will not reject the organs. Stem cells may be harvested and reimplanted to enable humans to regenerate their own organs—or so cutting-edge researchers believe.

Cancer presents the largest target and what may be the greatest challenges for molecular biology. Cancer results directly from the breakdown of genetic instructions for cell replication. The result is unlimited and uncontrolled cell growth. Understanding the multiple mechanisms by which genes instruct cells on when to divide and to self-destruct and the many ways error creeps into these instructions is the first objective. Techniques designed to check abnormal cell growth include antibodies and enzymes that inactivate the receptors that tell the cell to divide and factors to inhibit growth of the blood vessels that nourish the rapidly growing cancer tissues. Other interventions will facilitate the normal processes of cell death, which are suppressed in cancer cells, or will reverse mutations that block natural body defenses against cancers. In an interesting twist on the virus problem, viruses will be used to infect or poison cancer cells.

Molecular biology also carries hope of preventing or curing cardiovascular illness, the number-one killer disease in the United States. Some people have a genetic predisposition to high levels of the form of cholesterol associated with cardiovascular disease. Interventions to correct this defect or to block it from boosting cholesterol would reduce the likelihood of heart disease. Effective measures to encourage the growth of blood vessels could spare victims of coronary thrombosis from the damage to the heart that results from blocked coronary arteries. Recent work also indicates that inflammation of the coronary arteries may be responsible for as many as half of heart attacks.

Perhaps the greatest medical advance of the twentieth century is the development of antibiotics. Unfortunately, strains of bacteria have emerged that resist all known antibiotics. Now that the genomes of many pathogens have been identified and the genes responsible for the harmful effects have been brought into view, molecular biology represents the best hope of forestalling this threat. With that understanding, scientists will be able to design therapeutic agents that circumvent these bacterial defenses. Prospects are also improving for the development of agents that successfully combat viral infections, which with few exceptions have resisted treatment.

As the twenty-first century begins, the hit-or-miss search for new drugs and for other ways to cure or prevent many illnesses is ending. A new era is emerging in which scientists work from a fundamental understanding of cells, proteins, and genes to design interventions that reverse, block, or otherwise forestall illnesses. In the words of the Nobel prizewinner Alfred Gilman, scientists are now "able to complete [their] understanding of the wiring diagram of the signaling switchboard in each type of cell." With that knowledge in hand, they now—or soon will—have the means to design drugs or to directly change how cells operate to correct the genetic defects that each person inherits or acquires during life from mutations or other sources.

Molecular biology also provides weapons for combating a few illnesses that have become increasingly frequent as incomes have risen—obesity and senile dementia. Increasing incomes and decreasing activity are leading to a veritable epidemic of diabetes and other illnesses of the indolent overfed. An emerging understanding of cell metabolism and the brain chemistry that leads to overeating is helping scientists to find other ways to prevent or lessen the harmful consequences of excessive caloric intake.

While cancer has historically been the paradigmatic dread disease, senile dementia—Alzheimer's disease in particular—has become the new terror of those who can expect to live into old age. With improved understanding of the process by which this disease corrodes cognitive capacity and then destroys personality and physical functioning is coming the realistic prospect of interventions to prevent the disease or forestall its harmful consequences. Whether increased longevity will be a blessing or a curse, for the elderly themselves and for society, hinges in part on the success of this endeavor.

Our Uncertain Demographic Future

Even without accelerated medical advance, demographers project that longevity will increase and that the elderly will comprise a growing proportion of the U.S. population. Biomedical advance could intensify these trends. The reduction in mortality from heart disease by more than 50 percent since 1960 demonstrates the feasibility of such improvements.

Henry J. Aaron and Benjamin H. Harris explore the demographic implications of accelerated reductions in mortality rates and review various demographic models for human mortality. One such model suggests that reductions in mortality rates could average 2 percent a year, approximately the rate of decline in Japan during the 1970s and 1980s. According to another view, mammalian life span has a natural limit. After reproduction, it is argued, survival serves no useful evolutionary purpose, and early demise after reproduction may aid evolutionary success by reducing pressure on resources. The finding by the nineteenth-century scientist August Weismann that cells stop reproducing after a certain number of divisions seems consistent with this hypothesis.[1]

Even if a natural limit exists, however, the practical questions are whether that limit is near or much above current average life span and what can be done to modify those processes. Aaron and Harris conclude that the most helpful theory of the aging process is an analogy of humans to a machine that consists of many components, each essential for the machine's operation. Each component remains functional until too many of its constituent parts fail. Engineers have shown that machines fail over time in patterns that closely resemble human mortality rates. The machine model suggests that medical progress comes through interventions that prevent or postpone the failure of the constituent parts of each of the biological systems essential for life.

Rapid reductions in mortality rates quickly affect longevity but alter the population profile only with considerable delay. Social Security Administration projections, which assume no acceleration in reductions in mortality rates, posit that people born in 2030 will have a life expectancy at birth of just over 84 years; for those born in 2075, the average is 86 years. But if mortality rates decline 2 percent a year, babies born in 2030 could expect to live 104 years, and those born in 2075, more than 115 years. Even this rapid rate of improvement would not have much effect on the population distribution until the second half of the century. During the first half, the dominant event will be the aging and retirement of the baby-boom generation.

Whether reduced mortality increases or reduces disability depends on whether mortality is measured as years since birth or as years until death. If disability rates depend on years since birth, the number of disabled would skyrocket as the aged population rises. If it depends on years until death, disability would probably change little. The same holds for the cost and burden of supporting the elderly and the disabled. If delayed aging or public policy encourage later retirement, the ratio of retirees to active workers might increase only slightly. If current retirement age patterns persist, however, the cost of increased longevity would rise sharply as people spend ever more years outside of the labor force.

Work

If the proportion of each age group that works is unchanged, declining mortality cannot much affect the labor force. The reason is that few of the

1. See Gavrilov and Gavrilova (1991).

elderly work. Even if their numbers greatly increased, the impact on the labor force would be tiny. Only if people change the timing of retirement could increased longevity have large labor market effects. Gary Burtless poses the question of whether such changes are likely.

Economic theory by itself does not suggest that increased longevity will cause people to change their retirement plans—unless public policy is changed. If increased longevity does not affect wage rates, workers could rationally choose to allocate their increased life expectancy entirely to work, entirely to leisure, or partly to both. Each choice is consistent with the precepts of economic theory. Historically, longevity and incomes have risen and men have retired at progressively earlier ages. Increasing longevity could encourage later retirement if it changed the lifetime earnings profile. Because most workers earn less when old than when middle aged, the cost of retiring, measured by loss of potential lifetime consumption, declines as workers age. If increasing longevity keeps workers' productivity and earnings high until later ages, increased longevity would boost lifetime consumption possibilities. On the other hand, if the added years are ones of very low productivity, average lifetime consumption would necessarily fall.

Many private pension plans encourage retirement because annual benefits do not increase enough when workers defer retirement to ensure them the same total lifetime pension benefit they would receive if they retired earlier. Changes in pension policy that maintain the value of lifetime benefits if workers defer retirement would remove this disincentive to work.

Burtless finds little in economic theory or empirical evidence to suggest that sharply increased longevity will have a major direct effect on retirement behavior. But increased longevity would boost pension costs, which in turn would probably force changes in public policy to encourage workers to extend their working lives. Higher pension costs would necessitate sharply higher charges on workers to support public pensions, greatly increased contributions by workers or their employers to support private pensions, higher taxes to support public pensions, benefit cuts, or increases in the age at which pensions are first paid. All of these changes would likely cause workers to stay in the paid labor force longer than they now do.

Government Finance

Increased longevity is certain to have a large effect on government revenues and spending. It will increase revenues if it leads to extended working lives. A larger labor force would earn and produce more. The resulting increase in taxes could largely or fully offset increased spending to support an increased elderly population. But estimating the impact on revenue of an enlarged work force is subject to enormous error and uncertainty.

To sense the magnitude of effects flowing from increased longevity, one can consider the consequences of a 10 percent increase in average working lives, which would add about 7 percent to output if the added years of work were of unchanged quality—that is, if the education, experience, and other worker characteristics were unaffected. Such an increase in output would boost government revenue by $150 billion to $200 billion in 2004. While the actual increase could be considerably larger or smaller, it clearly would offset many of the added costs of a growing elderly population.

Increased longevity would also boost government spending. John B. Shoven provides estimates of this impact on the three largest domestic government programs serving the elderly: Social Security, Medicare, and Medicaid (programs that also, incidentally, serve the nonelderly). Outlays for all three programs are projected to grow rapidly as the baby-boom generation becomes eligible for benefits. The question that Shoven considers is whether a major reduction in mortality rates would significantly increase spending above these steeply rising trends.

Social Security costs, measured as a share of taxable earnings, are officially projected to nearly double between now and 2080. The payroll tax necessary to just cover outlays for Old-Age, Survivors, and Disability Insurance is projected to increase from just under 11 percent to just over 20 percent. This projection assumes that mortality rates will decline by about 0.6 percent annually. If mortality rates were to fall 2 percent annually but the duration of working lives were to stay at the official projection, the cost of Social Security would rise to more than 25 percent of payroll. A policy of raising the age at which full Social Security benefits are paid by one month a year starting in 2018 would eliminate most of the additional longevity-related cost. Shoven's message is simple and clear: As longevity increases, so too do Social Security costs.

Projecting the effects of longevity on Medicare and Medicaid costs is much trickier because program outlays depend not only on the number of beneficiaries but also on trends in the per capita costs of medical care. Medical spending is projected to rise over time as new technologies become available. But medical spending also rises with age because people's bodies gradually wear out or become subject to disease. Shoven considers whether increasing longevity would change the age profile of health care spending. According to one view, decline is an immutable consequence of age since birth. Increased longevity means that more people will reach ages when per capita medical costs are high. According to another view, which Shoven regards as more plausible, medical spending depends not on years since birth but on years until death. In this view, if the eighty-year-olds of the future have the same remaining years until death as, say, today's sixty-five-year-olds, then the ratio of the cost of medical care for these eighty-year-olds to the health care spending for, say, forty-year-olds will be the same as today's ratio of health care spending for sixty-five-year-olds is to that of forty-year-olds. Various facts persuade Shoven that the second view is the more plausible, including the fact that disability rates have been falling as mortality rates have been improving.

The difference between projections based on these alternative assumptions depends directly on the speed with which mortality improves. Under all assumptions, projected Medicare and Medicaid costs will increase greatly because per capita medical costs for everyone will increase. If mortality declines at historical rates, as assumed by government actuaries, projections based on the years-since-birth assumption show 2070 Medicare costs as a portion of gross domestic product at about 2 percent more than costs projected using the years-until-death assumption. The difference jumps to roughly 5 percent of GDP if mortality rates fall 2 percent a year. In the case of Medicaid, the cost difference in 2070 between projections is a bit over 1 percent of GDP if mortality declines at officially assumed rates but is nearly 6 percent if mortality rates fall 2 percent a year.

The story that emerges is straightforward. Costs of Social Security, Medicare, and Medicaid will rise during the early part of the twenty-first century. The major reasons are the aging of the baby-boom generation and, in the case of the health programs, the assumed general increases in medical costs. Accelerated increases in longevity will make their effects felt primarily in the second half of the century and beyond. How much health costs rise depends on whether reduced mortality is associated with delayed physical decline. If it is, then the added effect of increased longevity on health costs will be modest. If working lives increase, the added revenues from increased output of an enlarged labor force will help defray these costs.

Alan M. Garber and Dana P. Goldman examine in more detail whether increased longevity will slow the age-related increase in health care spending. They conclude that such a delay is quite likely. Nonetheless, they calculate future health spending based on the alternative assumption—that relative health expenditures on various age-sex groups will remain unchanged. They begin by projecting how many people in various age-sex categories will be alive in the future and how much will be spent on health care if disease prevalence is unchanged. Medical advances may well reduce the prevalence of some diseases. Changes in behavior—the increase in obesity, for example—could boost the frequency of other diseases. They proceed by estimating how much the elimination of one disease—like heart disease, diabetes, or cancer—will change health care spending. The effect is a significant, but modest, decline. Reductions are largest in the case of heart disease and smallest in the case of cancer. The reason for the difference is that heart disease strikes middle-aged people more than does cancer, which occurs predominantly among the old, when other fatal illnesses also often strike.

Trends in health care spending are acutely sensitive to insurance coverage. Garber and Goldman point out that rapid increases in the cost of new medical interventions will have two offsetting effects. They will increase the need for health insurance, but they will also raise the price of insurance. As a result, insurance may become too costly for many, especially those with low incomes, to afford. If rising health costs swell the ranks of the uninsured, they could intensify ethically troubling inequalities in access to what is likely to be increasingly beneficial medical care.

The extent and nature of health insurance also influences the nature of medical innovation. Health insurance weakens the sensitivity of patients to the price of health care because third parties bear much of the cost at the point when it is used. Such price insensitivity encourages the development of high-quality, high-priced services rather than somewhat lower-quality but lower-priced services. If rapid growth in the cost of health care causes more people to be uninsured or to elect less complete coverage, Garber and Goldman hypothesize that the increased cost sensitivity of patients will cause the development of lower-cost innovations.

A Global Perspective

The effects of a sharp increase in longevity would not be confined to a single nation. The swelling ranks of the elderly threaten pension systems in many nations and may have important effects on international capital flows. Economists have studied the effects of demographic change on national saving, investment, and output. These studies provide some basis for anticipating the consequences of the dramatic increase in longevity examined in this book.

Barry P. Bosworth and Benjamin Keys present new estimates showing that such a development would render retirement systems in most developed nations unsustainable without significant changes. These trends could also prevent many developing nations from borrowing to finance growth because of declining saving rates in developed nations. (Changes in labor force participation and in immigration could modify these projections, but Bosworth and Keys do not consider these.)

Declining birth and mortality rates have occurred in nearly every nation at some time during the past 150 years. Whether birth or mortality rates fell first and by how much strongly influences a nation's population profile. From the standpoint of economic development, the ideal pattern is a drop in birth rate followed some years later by declining mortality. This pattern produces a period during which the ratio of the working-age population to the total population is high. Because the cost of the economically inactive is low during this period, domestic saving can support high rates of investment. Eventually, however, the aged population increases. If birth rates remain low, overall population, excluding immigration, will fall.

Bosworth and Keys point out that if major increases in longevity depend on costly medical interventions, they are likely to be confined to wealthy nations. Because mortality rates are already low among those under age fifty in developed nations, the principal effects of declining mortality rates are likely to show up as increases in the size of population groups over age fifty. The largest increases in the ratio of the elderly to the working-age population would therefore occur in wealthy nations. The effects in middle-income nations would be modest and in poor nations very small. The most extreme effects would show up in nations such as Japan, where the elderly population is already 71 percent as large as the working-age population. If mortality rates fall 2 percent a year, the elderly population could grow to 117 percent of the working-age population. The effect in the United States will be much smaller because above-average birth and immigration rates are projected to maintain some growth of the working-age population.

Bosworth and Keys find that currently foreseen population aging is likely to cause both saving and investment to decline in high-income countries. In both middle-income and poor nations, saving would increase. These shifts would push the foreign trade balances of rich nations into deficit and those of the rest of the world into surplus. Reductions in mortality rates of 2 percent annually, the central assumption of this volume, will intensify these effects. Saving would decline sharply, investment somewhat less. Because the impact of medically based increases in longevity are likely to be greatest in nations that can afford such innovations, these results suggest that increasing longevity will be associated with trade deficits in rich nations.

Bosworth and Keys emphasize the sensitivity of their results to a variety of factors that they do not examine. Among the most important are how increasing longevity affects labor force participation. If people work until older ages, the increased labor force will create a demand for additional investment, lower the cost of private and public pensions, and reduce the amount that individuals need to save on their own to sustain preretirement living standards. Technological change influences investment opportunities and the call on saving to finance that investment. But regardless of the strength of these influences, the core fact remains: Extending longevity is likely to be quite expensive, and rich nations are more likely than poor nations to incur those costs.

The Ethical Dilemmas of Increasing Longevity

The prospect of an engineered extension of human life has created a major stir among ethicists, some of whose theories Alexander M. Capron examines. Such interventions should be evaluated, he suggests, on three criteria. Is the goal legitimate? Are the means to achieve the goal acceptable? Are the consequences benign? Capron divides ethical questions into three categories: interpersonal, intergenerational, and fundamental (meaning questions regarding the basic legitimacy of efforts to extend the human life span).

To begin with, Capron points to the obvious fact that interventions that have extended human lives are not exactly new. Throughout the twentieth century public health advances, rising income, and medical discoveries combined to add decades to life expectancy at birth. The decline in infant mortality and the lives saved by antibiotics raised few moral questions. To be sure, life extension resulting from these sources has brought a variety of practical problems, such as how to pay for pension and health costs for the elderly. They have raised some ethical problems as well: whether it is ever right—and if so under what circumstances and after what steps—to curtail care for extremely ill patients or to allow severely damaged newborns to die. In the past anyone who ever questioned whether clean water, the reduction of poverty, or effective antibiotics were ethically desirable would have been regarded by most people as deranged, but the problem, Capron argues, is now different. Past life-extending developments simply extended to the many the opportunities previously available to the few. In contrast, he suggests, some interventions now in prospect would change the fundamental character of humans—by changing their genes or replacing their organs, for example.

The ethical issues raised by life extension depend in part on the consequences of life extension. To sharpen this point, Capron (adopting a suggestion of his discussant, Margaret P. Battin) presents several possible scenarios of life extension. The most benign scenario, he suggests, is if human decline mimics that of Oliver Wendell Holmes's wonderful one-hoss shay, which lasted a hundred years and a day and then instantly fell apart. The most problematic scenario is an increase in the average age at death without any decrease—and possibly with significant increase—in the amount and duration of physical and mental decline. If one knew in advance which of these outcomes would materialize, it would be possible to judge the desirability of the result. But as Capron points out, no one can foresee whether the myriad scientific advances contributing to the extension of life will add decades of mental and physical vigor or decades of senility and debility.

The ethical issues raised by life extension will also be shaped by the means used to achieve that end. Capron argues that irreversible interventions, such as alteration of human genes, raise more questions than do interventions that can be stopped, such as a hormone that a patient can stop taking. Other issues concern payment: When does a service become standard and normal and therefore one that private and public insurance are expected to cover, and when may it be regarded as experimental and be legitimately excluded from standard insurance? The larger point is that many of the innovations that hold the promise of extending life will require risky experimentation that itself requires stringent procedural safeguards.

Capron also addresses social questions that sharply increased longevity could raise. The first concerns the added costs for public pensions and health benefits that a larger aged population will generate. Capron argues that fairness dictates that some of these costs should be borne by the beneficiaries of these services through longer working lives and notes that the feasibility of this form of cost sharing depends sensitively on which pattern of physical decline eventuates. Another issue concerns the fairness of access to life-extending interventions. Capron dismisses the views of some ethicists that after the achievement of a "normal" life span equitable access to life-extending care is not ethically required. Both the duration of normal lives and the content of normal interventions is inescapably elastic. Both depend on expectations that are themselves influenced by technological possibilities. Finally, Capron points to suicide and passive euthanasia as questions that are likely to become increasingly prominent. Should the failure to use the capacity to extend life be regarded as euthanasia? Or is it suicide if patients actively reject such treatment?

Capron concludes his exploration of ethical issues by confronting the criticisms advanced by Leon Kass, Francis Fukuyama, and others that life extension is not a legitimate goal of science and that success in such an endeavor threatens to deprive people of essential attributes of their humanity. Finitude, it is argued, lends life savor, sweetness, and value. The quest for superhuman intelligence, looks, or longevity is quite literally inhuman. Gradually, step by step—like the person immersed in a bath gradually warming from comfortable to lethal—humans would surrender what it means to be human by a series of steps each seemingly reasonable but cumulatively dehumanizing. Capron holds that these concerns are far less likely to have substance than those arising from the possibility that successful life extension could easily produce a dystopia with ever-larger parts of life spent in dependence.

The title of this collection of essays invokes the name of the biblical figure alleged to have lived longer than anyone else: 969 years. Methuselah's life was relatively uneventful, if fathering a child at age 187 can fairly be described as uneventful. His grandson, Noah, lived nearly as long and, by some standards, went through a good deal more stress. This comparison highlights two important facts: that longevity seems to run in families and that lives of similar duration may be associated with both easy and troubled times.

A well-known Scottish economist, sensitive to the vagaries of prediction, advised forecasters, Give a number or a date; never both. We think that the scenario addressed in this book—a world in which living to a hundred or even beyond will one day be common if not typical—is a reasonable extrapolation of the revolution in molecular biology that is only now gaining momentum. That is the number. No one can forecast the date. The various threats to extended life—pandemics, terrorism, and the remarkable capacity of humans to behave self-destructively—may offset part or all of what biomedical science does. After all, the twentieth century witnessed remarkable advances in science, public health, and income, all of which contributed to longer life expectancy, but increases in life expectancy did not accelerate. Past rates of increase in longevity could continue or even slow. But we believe that a flowering of biomedical science is at hand and that it has created another possibility—still by no means a certainty—that declines in mortality rates will accelerate.

This book is dedicated to the proposition that it is worth thinking seriously about the implications of such a development. Writers always place utopias and dystopias in the imagined future. Qualification or complexity do not dilute these worlds, elysian or hellish, because they are imaginary. Readers may be repelled by the nightmares of the *Brave New World* or *1984,* chilled by the cold impersonality of *The Rise of the Meritocracy,* or swept by the romantic notions of *Looking Backward.* The authors of these imagined futures had a free hand to paint with their chosen palettes.

Historians and social scientists, in contrast, have no such license. The contributors to this volume have written with academic detachment about some of the problems we may face if living to ninety, a hundred, or beyond becomes common. What emerges are problems, challenges, and opportunities. Utopias do not adorn the pages of honest histories and analyses.

Reference

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