Commentary

Passage to Methuselah: Some Demographic Consequences of Continued Progress against Mortality

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Abstract: How will progress against mortality affect the size and age composition of the United States population over the next century? To gain some insight into this question, three scenarios are examined: no future progress against mortality; steady reductions in mortality at all ages at a rate of 2 per cent per year; and a radical breakthrough in the year 2000 that cuts mortality in half. All three scenarios substantially shift the composition of the US population toward older ages, steady progress resulting in the most radical change. If mortality is reduced 2 per cent per year, by 2080 almost two-fifths of the population would be above age 65 and the number of centenarians would approach 19 million. The social, economic, and public health consequences of this new demography, although speculative and uncertain, are so important that detailed analysis and planning are warranted. (*Am J Public Health* 1986; 76:430–433.)

Introduction

Suppose progress continues to be made in reducing mortality rates at all ages. What impact would this progress have on the size and age composition of the United States population?

The supposition that mortality rates will continue to fall is admittedly questionable. The view popularized by Fries is that, "the median natural human life span is set at a maximum of 85 years with a standard error of less than one year."[1] Demeny, in making long-term population forecasts for the World Bank, assumes that even by the year 2100 there will be no country with a life expectancy above 82.5 years.[2]

Demeny notes that in some countries life expectancy seems to be slowly decreasing. The possibility of a general decline in life expectancy cannot be ruled out. On the other hand, as Demeny points out, "the upper limit to life expectancy" of 82.5 years "may yield to technological changes in medicine and to changes in life styles, perhaps even within the next few decades."[2]

As documented by Crimmins,[3] remarkably rapid progress in reducing mortality rates was made in the United States from 1968 to 1977. This progress has continued and even accelerated from 1977 to 1984. At most ages, including older ages, mortality rates over the last decade and a half have been declining at a rate of 1 or 2 per cent per year.

Hope that this progress might continue is buttressed by recent advances in the biological, medical, and gerontological sciences. The life sciences appear to be poised at roughly the point the physical sciences were a century ago and breakthroughs comparable to electricity, automobiles, television, and computers may be forthcoming in the areas of genetic engineering, prevention and treatment of such diseases as atherosclerosis, cancer, and diabetes, and perhaps understanding and control of the process of aging itself.[4–6]

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As argued by Manton,[7] the only judicious position to take, in light of the conflicting evidence and theories about the rate and direction of future mortality change, is to admit uncertainty. There is a chance that mortality rates will continue to decline at recent rates; there is a chance this progress will level off; there is a chance that mortality rates will increase; there is a chance of some major breakthroughs that will radically reduce mortality rates. Given this uncertainty, it seems reasonable to try to gain some understanding of the demographic consequences of alternative mortality scenarios.

In this commentary, we explore three possibilities: no change in mortality rates; continued progress at 2 per cent per year at all ages; and a radical breakthrough that cuts mortality rates in half in the year 2000. To study continued progress against mortality, we needed mortality rates at advanced ages, well beyond the usual stopping point of 85: we based the rates we used up through 119 on Faber's actuarial study[8]; after this age we made the conservative assumption that mortality rates increased by nearly 9 per cent per year. All the calculations we make are optimistic in that we ignore the possibility of nuclear war and other catastrophes.

Our focus is on the impact of such scenarios on the size and age composition of the US population. Because our aim is insight and not prediction, we will initially assume that fertility rates stay unchanged and that net migration amounts to zero: these simplifications avoid obscuring the effects of mortality change with fertility or migration change. Then we will briefly consider the difference fertility and migration might make.

No Change in Mortality Rates

If age-specific mortality rates stay at 1980 levels (and if age-specific fertility rates also stay unchanged and there is no net migration at any age), then the age composition of the United States will change over the coming century as indicated in the left-most column of Table 1. It may seem surprising that no change produces so much change: the shift in the age composition results from the differences in historical levels of mortality and fertility compared with the 1980 levels.

TABLE 1—Age Distribution of US Population in 1980 and in 2080

Age Category	In 1980 Number (in millions)	In 1980 (%)	In 2080 if Age-specific Mortality Rates Stay at 1980 Levels Number (in millions)	Stay at 1980 Levels (%)	Decline 2% per Year Number (in millions)	Decline 2% per Year (%)	Are Cut in Half in 2000 Number (in millions)	Are Cut in Half in 2000 (%)
Under 20	72	(32)	48	(23)	51	(18)	50	(21)
20–64	129	(57)	117	(57)	128	(45)	124	(52)
65–84	23	(10)	36	(17)	57	(20)	47	(20)
85+	2.2	(1)	5.3	(2.6)	51	(18)	17	(7.1)
Total	227	(100)	206	(100)	286	(100)	238	(100)

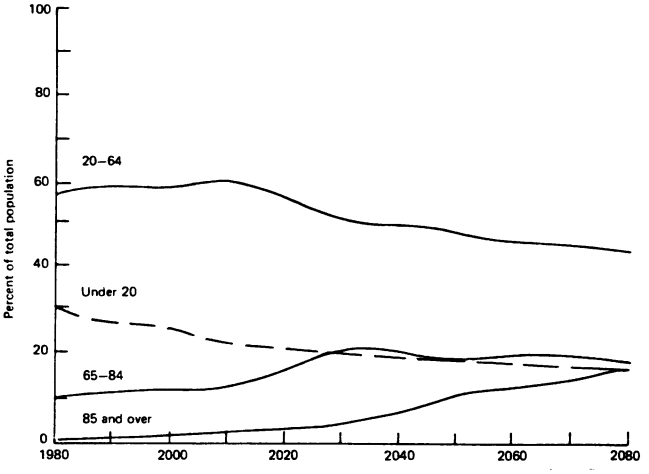

FIGURE 1—The Evolving Age Structure of US Population if Age-specific Mortality Rates Decline at 2 Per Cent per Year

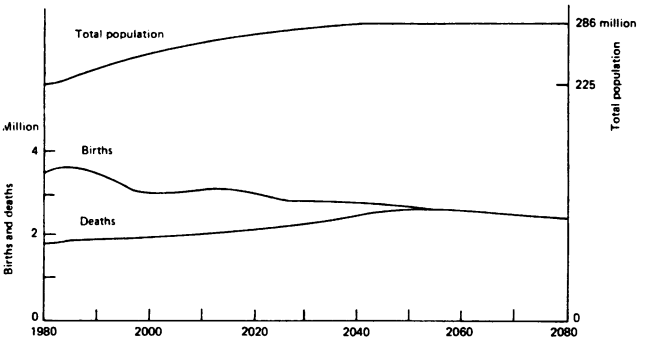

FIGURE 2—US Births, Deaths, and Total Population from 1980 to 2080 if Age-specific Mortality Rates Decline at 2 Per Cent per Year

Compared with 1980, the proportion of the population under age 20 declines by more than a fourth, the proportion in the prime years from 20 to 64 stays constant, and the proportion above age 65 almost doubles from 11 to 20 per cent. Centenarians, who numbered 20,000 in 1980, multiply to nearly 110,000 in 2080: the scarcity of centenarians today is a legacy of high mortality rates and smaller population sizes a century ago.

Even though the 1980 fertility rates are below replacement level, the US population will continue to grow under this scenario, from 225 million in 1980 to 254 million in 2020. As the population ages, however, and the reverberations of the baby boom dampen out, deaths overtake births and from 2020 to 2080 the population declines to 206 million.

Steady Progress

Suppose mortality rates continue to decline at all ages at a rate of 2 per cent per year. As shown in Table 1 and in Figure 1, this steady, gradual progress would radically transform the age composition of the US population in a century. By 2080, the proportions of the population under age 20, between ages 65 and 84, and above age 84 would be about the same, 18–20 per cent in each case. The population between ages 20 and 64 would correspondingly decline to 45 per cent of the total. As these proportions suggest, the age structure of the population would be roughly level from birth to age 100. The population would fall off above age 100, but it would not be unusual to survive to 125 and a few hardy individuals would be 140 or more. The total number of centenarians would approach 19 million and nearly 400,000 of them would be at least age 125. Those 400,000 will have been born before 1955; one of us (Gowan) will only be 117 in 2080.

In 1980, about one person in 1,000 was above age 90; in 2080 under this scenario, about one person in seven would be above age 90 and more than one person in 1,000 would be above age 125.

Figure 2 shows the trends in births, deaths, and total population size. Births gradually decline and deaths increase until they meet and then slowly decline together: the progress in reducing mortality offsets the low level of fertility so that population size remains constant, at 286 million.

A Breakthrough

Suppose at the turn of the millennium a breakthrough was made that cut mortality rates in half at all ages, but that

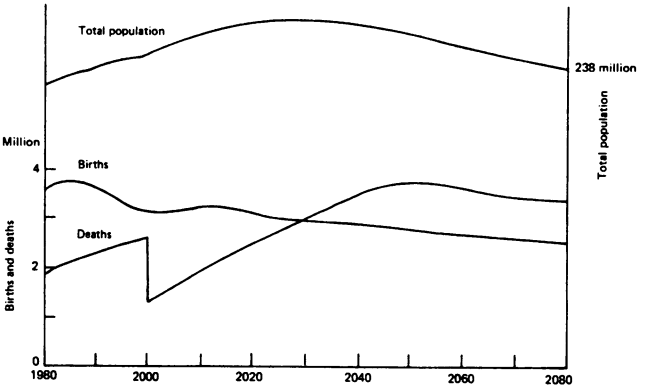

FIGURE 3—US Births, Deaths, and Total Population from 1980 to 2080 if Age-specific Mortality Rates Are Cut in Half in 2000

before and after this breakthrough mortality rates remain unchanged. Figure 3 shows the effect on deaths, births, and total population. By 2030, deaths overtake births and the total population declines by 2080 to 238 million. As shown in Table 1, the age structure of the population in 2080 is intermediate between the structure with no progress and the structure assuming 2 per cent annual progress. Indeed, this age structure is similar to the structure that would emerge from steady 1 per cent progress against mortality.

Just as the tortoise in Aesop's fable creeps along at a deliberate pace and overtakes the resting hare, steady 2 per cent progress amounts to more in a century than a one-time 50 per cent reduction. In fact, with steady 2 per cent progress mortality rates at each age would be cut to about one-eighth of their original level in a century.

Insight, Prediction and Projection

Demographers often distinguish between prediction and projection: predictions purport to foretell the future, whereas projections are extrapolations from the present based on some specified procedure. Certainly not predictions, the calculations presented so far can hardly be called projections, because they assume constant fertility, no net migration at any age, and unrealistically regular patterns of change in mortality. Any demographer could come up with more sophisticated projections and many have done so.

The drastic simplifications were made deliberately. If buzzing complications are suppressed, then the impact of progress against mortality on the size and age-structure of a population can be more clearly perceived. Thus the purpose of the calculations was neither prediction nor projection, but insight.

The gist of the calculations is that continued progress against mortality will somewhat increase the size of the US population, largely by adding a surprisingly large number of people over age 85. Even if there is no future progress against mortality, past progress will produce a tripling of the very old population within a century. A breakthrough that substantially cuts mortality is not needed to radically alter a population's age structure; indeed, steady 2 per cent progress has a much greater impact over the course of a century than a one-time halving of mortality rates.

The calculations were aimed at isolating and capturing what might be called the force of steady mortality progress. The operation of this force will be somewhat obscured by other forces, including the force of differential mortality progress at different ages, the force of fertility change, and the force of net migration. Some simple arithmetic, however, indicates that these other forces are unlikely to reverse a trend toward a fundamental shift in the age structure of the US population.

Consider differential mortality progress. Death rates before age 60 or so in the United States are so low that the calculations presented in this commentary would hardly change if these death rates either remained constant for the next century or were reduced to zero tomorrow. Early deaths nonetheless remain a central public health concern and are even more significant than deaths in old age from a number of perspectives.[9] What will determine the age distribution of the US population is the rate of progress in reducing mortality after age 60 and especially after age 80. If much less progress is made over the next century at ages above 80 than is made between ages 60 and 80, then there will be far fewer people in the 85+ population than we have calculated. It is conceivable, however, that the rate of progress at very old ages will be substantial, and it is this possibility that we have explored. For example, using single-year-of-age mortality figures published for 1970 and 1980, it can be calculated that mortality rates for females were reduced by 1.6 per cent, 1.3 per cent, 2.0 per cent, and 1.2 per cent per year over this decade at ages 60, 70, 80, and 90, respectively.

Since everyone who will be 95 or more in 2080 has already been born, changes in fertility levels are irrelevant for calculations of numbers of the extremely old. Even for cohorts not yet born, fertility change is likely to be far less significant than mortality change in altering the size of the elderly population. A 25 per cent rise in the number of births a decade from now would correspondingly increase our population estimates for 85-year-olds by 25 per cent. This can be compared with the ten-fold increase in the 85+ population if progress against mortality is 2 per cent per year instead of being negligible, as shown in Table 1.

As indicated in Figures 2 and 3, our calculations assume roughly three million births per year, somewhat more in the near future and somewhat less a century hence. If a million births were added or subtracted every year, the size of the US population would substantially change, but the age composition of the population in 2080, up to age 95, would be unaffected. If births were added in some decades and subtracted in others, population waves would be set up, similar to the waves resulting from past baby booms and busts that can be detected in Figures 1, 2, and 3, but the underlying pattern would persist.

A steady increase in the number of births each year would decrease the proportion of the population that is elderly, although it would also somewhat increase the number of people reaching old age. Conversely, a steady decline in the number of births would have the opposite effects: the elderly would be less numerous but relatively more important.

Net immigration to the United States will increase population size. Its impact on the age composition of the population can be thought of as being similar to the impact of births that occur around age 20, assuming that is the peak age of immigration, as opposed to the usual births at age zero. Hence migration, like fertility, is unlikely to fundamentally alter the effects of progress against mortality on the age composition of the US population. Migrants grow old too, and a 20-year-old migrant will reach age 85 some 20 years before a newborn does.

Adjusting to the New Demography

In sum, whether there is no further progress against mortality, steady progress at 1 or 2 per cent per year, or some breakthrough that substantially cuts mortality rates, the age structure of the US population (and of the populations of most other developed countries and many developing countries as well) seems likely to shift toward older ages. If the life sciences over the coming century produce advances similar in impact to the advances produced by the physical sciences over the last century, the cumulative shift may be radical. Even in the case of revolutionary breakthroughs, however, the shift will occur gradually: if death were eliminated tomorrow it would still take a century before there would be many 200-year-olds. So society will have time to adjust to the new demography.

Nevertheless, it may be worthwhile to begin speculating about some of the adjustments that might have to be made, not only to start developing the wisdom that will be needed to successfully cope but also because some current decisions

depend on long-run trends.[10] These adjustments unfortunately depend on a crucial uncertainty: will increased life expectancy be accompanied by increased healthy, productive life expectancy? Jonathan Swift, in the section of his *Gulliver's Travels* on the Luggnaggians, describes some of the pleasures and opportunities that would open up if people could live long, vigorous lives and then contrasts this vision with the misery of the immortal but decrepit struldbruggs and their drain on society. Who would wish to live to age 120 in, as Shakespeare wrote, "mere oblivion, sans teeth, sans eyes, sans taste, sans everything." The evidence, as reviewed by Manton,[7] is weak and mixed on morbidity and disability trends in old age; more research is needed.

In any case, given the likely expansion of the population of the elderly, it would seem to be prudent to place a very high priority on the development of ways of delaying or alleviating debilitating conditions. Promising directions here include not only biomedical treatments and cures and the promotion of healthy personal behavior, but also the design of appropriate living environments and of helpful products like voice-activated robots.[11]

If progress is made not only against mortality but also against morbidity, perhaps through progress in slowing the process of aging itself, people may wish to work longer. Furthermore, as the proportion of the population over age 65 begins to approach the proportion between ages 20 and 64, delayed retirement will almost certainly be required to save Social Security from bankruptcy. If more of the elderly hang onto their jobs, however, promotional opportunities will diminish for the young and whatever gain there may be in wisdom and experience in an organization may be offset by a lack of fresh thinking and new blood. In addition, the increase in the proportion of the elderly might result in a further shift of political power and even greater governmental focus on the needs of the elderly and inattention to the needs of the young.[12] A major challenge to society will be to develop career patterns and social norms that enable the elderly to productively contribute while simultaneously giving the young a chance.

When lifespans reach or even exceed a century, the division of life into three successive stages of education, employment, and retirement will undoubtedly have to be rethought. Not only to contribute productively to society but simply to understand society, octagenarians will have to have learned about the advances and changes that have occurred since they finished high school or college. Delaying the age of retirement to age 80 or 85 might permit periodic leaves from work—a year, say, every decade, for ongoing education. In addition, a reduction in the hours worked per week and an increase in the number of weeks of vacation per year might facilitate part-time education on a more or less continuous basis. The 64,000 hours or so of lifetime work under the emerging system of 35 hours per week, with a month's vacation plus scattered holidays, from age 22 to age 62, could alternatively be arranged so that a person works 28 hours a week, with two months' vacation per year and a year's leave every decade, from age 22 to age 82. If median lifespan approaches a century, that would still leave 18 years of retirement.

One of us (Vaupel) just had a baby daughter, Anna. In a companion article,[13] various estimates were calculated of her life expectancy. If progress is made against mortality at a rate of 2 per cent per year at all ages, then Anna's life expectancy is 102 years. This makes the year 2080 seem closer—Anna may well be alive then—and makes the changes discussed in this paper more immediately relevant—the changes are not only going to affect future generations but also people alive today. Indeed, as noted earlier, one of us (Gowan) may well be alive in the year 2080, at the advanced but not impossibly implausible age of 117.

Anna is going to have to decide, with some help from her parents, what kind of education she wants. Our hunch is that she needs an education that enables her to keep learning, because society and technology will change dramatically in her lifetime. In addition, she would probably benefit from a solid liberal arts education—in music, the arts, literature, history, the great books of philosophy and science—because this background, which helps a person maintain an active interest in life, is more readily acquired in youth than in old age. Finally, her education should certainly include an education in health, including knowledge of how personal behavior can affect health. Deleterious habits and addictions acquired in youth become even more tragic if they terminate what could have been a century of healthy life or if they bring on disabilities that last not for years but for decades.

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