16. Reverse mortgage insurance would protect the lender just as conventional mortgage insurance does. However, the nature of the risk is quite different. In the latter case a borrower's death may make the loan a nonperforming one, while in the former the borrower's long life may put the lender at risk.
17. See Jacobs and Weissert, *op. cit.;* Garnett, Robert, and Guttentag, Jack, "The Reverse-Shared-Appreciation Mortgage," *Housing Finance Review, 3*(1) (Jan. 1984): 63–84.
18. Another advantage of being married is that a spouse is available to provide informal care in the home if the need arises.
19. Firman, James, "Reforming Community Care for the Elderly and the Disabled," *Health Affairs, II*(1) (Spring 1983): 66–82. Frail elderly homeowners in California have taken out reverse mortgage loans for this purpose. See Kenny, Kathleen, and Belling, Bronwyn, "Home Equity Conversion: A Counseling Model," *The Gerontologist,* to appear.
20. Jacobs and Weissert, *op. cit.*, p. 88.
21. In addition to consumer ability to pay, other issues in the development of nursing home insurance require close attention. One of them is the problem of adverse selection, which occurs when those who buy insurance are disproportionately likely to need extended care. Another is induced demand (or "moral hazard"). Once insured, elderly people may substitute nursing home care for informal care previously provided by family or friends. Nursing home insurance policies will have to have provisions limiting the potential impact of these problems. See *Long Term Care: The Challenge to Society* (Washington, DC: Health Insurance Association of America, 1984).
22. See Smeeding, Timothy M., "Nonmoney Income and the Elderly: The Case of the 'Tweeners,' " Discussion Paper No. 759-84, Institute of Poverty Research, University of Wisconsin, Dec. 1984.
23. Weissert, William, "Size and Characteristics of the Noninstitutional Long-Term Care Population," *Health Care Financing Review,* to appear.

## ANNA'S LIFE EXPECTANCY

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Anna Bodil Vaupel was born on March 20, 1984. How long can she expect to live? The conventional, *Statistical Abstract* answer is 78 years. A more plausible estimate is 90–100 years, with a range of uncertainty stretching from three-quarters of a century to two centuries or more. The difference among these life expectancies is of some importance, to policymakers as well as to Anna's parents. When lifespans approach or even exceed a century, the division of life into three successive stages of education, employment, and retirement will undoubtedly have to be rethought. It will be a century before A.B. is a centenarian, so there will be time to adjust to the new demography. But changes in lifestyle and social structure may be so radical that it may be useful to start speculating now. Some policies with long-term consequences—as for education and financing retirement—may need careful rethinking soon.

Every year the Office of the Actuary of the U.S. Department of Health and Human Services releases estimates of life expectancy at birth. Recent estimates are that newborn boys can "expect" to

live about 71 years on average and newborn girls about 78 years. These calculations assume that mortality rates facing today's babies at each age of their expected life will remain at current levels: when Anna reaches age 60 in the actuarial year 2044, she thus faces the same hypothetical chance of death that year that a 60-year-old female faces today. This method summarizes *current* mortality at all ages. Although conventional "life expectancy" shows how well the U.S. is doing today compared with a decade ago or compared with Sweden or Japan, it does not truly project the future.

Anna Bodil will probably outlive her official 78 years because mortality rates are likely to fall considerably over the course of her life. Throughout this century great progress has been made in medicine, public health, sanitation and environmental quality, nutrition, safety, and personal health-related behavior. It seems implausible to suppose that such progress will come to a halt now, but it is harder to know how to project continuing improvements. Since there are numerous ways of thinking about progress, several kinds of calculations are presented here. Some assume continued progress at historical rates, others accelerated progress; another section considers steady progress against various causes of death.[1] The calculations are hopeful in that they ignore possible catastrophes such as nuclear war, as do the official estimates. All the projections are very approximate, but the message is clear: Anna's life will probably last many years longer than the official estimates.

**Projecting from Past Progress**

During the 1970s, mortality rates at most ages dropped at an annual rate of more than 1% per year, and at many ages the rate of progress exceeded 2% per year. This progress has continued and even quickened somewhat in the early 1980s. If progress against mortality at each age continues to advance each year at the same average annual rate as in the 1970s, Anna's expected lifespan will be 90 years, fully 12 years more than the official estimates give her. If conditions improve at these same rates indefinitely and Anna has a daughter at age 25, her daughter will have a life expectancy of 94 years. Projecting forward under the same assumptions, Anna's granddaughter can expect a lifespan of 97 years, and her great granddaughter can expect to be a centenarian.

Steady progress is not the only way to project, however. In fact, progress in reducing mortality rates has accelerated over the last two or three decades, especially at advanced ages. If this decade-to-decade acceleration continues, lifespans will increase even faster. The 1980s rate of progress in reducing each age group's mortality below the 1970s rate could grow proportionately as much as the 1970s did over the 1960s. If so, and if this acceleration continues for successive decades, then A.B.'s life expectancy increases from 90 to 93 years. Similar calculations for males yield a life expectancy of 97 years, which would finally give baby Alan better life chances than baby Anna. Very little progress was made in reducing male mortality rates in the 1960s, but there was considerable acceleration between the 1960s and 1970s.

A recent report of the Office of the Actuary makes different, more

**Table 1.** How long will 1984 babies live?

| Basis of projection | Baby girl | Baby boy |
|---|---|---|
| Official estimate (no further progress against mortality) | 78 years | 71 years |
| Continued progress against mortality as in 1970s | 90 | 81 |
| Progress continues to accelerate as it did from the 1960s to the 1970s | 93 | 97 |
| Progress tapers off to zero by the year 2050 | 83 | 75 |
| Progress is 2% per year at all ages | 102 | 94 |

cautious projections of future progress against mortality.[2] Rates of progress are assumed to decline steadily from current levels and to taper off to zero by the year 2050. Under these projections, Anna B.'s life expectancy is 83, some 5 years higher than the published estimate of current life expectancy.

Finally, suppose that the 1970s steady progress could be slightly improved from an age-weighted average of almost 2% per year to exactly 2% per year at all ages. Then Anna's expected lifespan increases to 102 years.[3]

Table 1 summarizes. By any calculations, if progress continues, life will lengthen substantially.

**Progress Against Causes of Death**

Mortality rates can be extrapolated not only by age and sex, but also by cause of death. Using published figures it is possible to project Anna's chance of dying from cancer at, say, age 72. If the rates of progress achieved in the 1970s against various major causes of death are extrapolated forward, Anna's life expectancy turns out to be 86 years.[4] As seen in Table 2, Anna would be more likely to die from heart disease than from any other cause if current mortality rates persisted. If the rates of improvement against the various causes of death continue unabated, then cancer will overtake all other causes of death. Although some progress is being made in reducing cancer mortality at younger ages, at older ages cancer death rates have tended to increase rather than decrease. This worsening at the ages when most people die, coupled with the dramatic improvements being made in cardiovascular mortality, leads to cancer's prominent role in the projections.

The projected probability of Anna's dying from violent causes, which include accidents, homicides, and suicides, is only around 1%. This estimate may be unrealistically low. The low estimate arises because substantial progress was made in the 1970s in reducing death from violence, especially at older ages. The accidental death rate among the elderly is a good measure of how unhealthy they are, and this progress may indicate improved health at older ages.

How would the eradication of cancer affect life expectancy? The conventional wisdom is that curing cancer would add only about

**Table 2.** What will a newborn eventually die from?

| Cause | Probability of dying from various causes | | | |
|---|---|---|---|---|
| | Assuming no progress | | Continued steady progress | |
| | Female | Male | Female | Male |
| Heart disease | 42% | 40% | 11% | 9% |
| Cancer | 18 | 20 | 44 | 67 |
| Vascular disease | 19 | 13 | 1 | 1 |
| Violence | 4 | 8 | 1 | 3 |
| Respiratory causes | 5 | 7 | 4 | 11 |
| Congenital causes | 1 | 1 | 1 | 1 |
| Digestive diseases | 2 | 2 | 1 | <1 |
| Diabetes mellitus | 2 | 1 | 3 | <1 |
| Liver cirrhosis | 1 | 2 | 1 | 2 |
| Other causes | 6 | 6 | 33 | 5 |
| Total | 100% | 100% | 100% | 100% |

two years to average lifespans.[5] At *current* rates, barely a fifth of males and females die from cancer, thus making a cure for cancer relatively unimportant in increasing life expectancy. As with life expectancy estimates, however, the picture changes if projections do not hold mortality rates constant, but instead allow them to change. If Anna faced no risk of death from cancer, her life expectancy would increase by a full decade, from 86 to 96 years. For males the eradication of cancer would dramatically raise life expectancy from 74 to 88 years.

Completely eliminating today's number one killer, heart disease, would only increase Anna's life expectancy from 86 to 87 years, because at current rates of progress, heart disease would be largely eliminated over Anna's lifespan anyway.

### Will Anna Meet Methuselah?

Although our estimates for baby A.B.'s lifespan substantially exceed conventional ones, they may turn out to be stodgy understatements. Biological, medical, and gerontological breakthroughs could lead to vast extensions of human life. The life sciences appear to be poised at roughly the point the physical sciences were a century ago, and biological applications comparable to electricity, automobiles, television, rockets, and computers may be forthcoming. Advances could occur in genetic engineering, prevention and treatment of such diseases as arteriosclerosis, cancer, or diabetes, and perhaps even in understanding and controlling human aging itself.[6] Anna will not reach the ages of high mortality for three or four score years; if breakthroughs are made in the interim, she may be given the benefit of another half century of life—during which major additional life-extending advances might be made. The possibility that she, or perhaps her daughter or granddaughter, will be reprieved to live two or three centuries, or even the nine centuries of Methuselah, may not be unimaginable after all.

The life of an individual who dies at 50—the life expectancy in the U.S. as recently as the turn of this century—is radically different from the life of an individual who dies at 100 or much more. Society will be different because of the change in its age composition. Elsewhere, we make some estimates of the evolving age composition in the U.S. population if progress is made in reducing mortality at a rate of 2% per year at all ages.[7] This pace of progress is not unreasonable given current rates of progress at most ages and the prospects for some biomedical breakthroughs; it projects a life expectancy for Anna Bodil of some 102 years. If fertility is held at 1980 levels, just below long-term replacement levels, and if net migration is assumed equal to zero, then this scenario leads to a population in the year 2080 in which the number of people between 60 and 100 would be roughly the same as the number of people between 20 and 60, about 100 million people in each case. Only half as many people, about 50 million, would be under 20, and nearly 20 million people would be older than 100, 400 thousand of them exceeding 125. (Anna, in 2080, will only be 96; that year's 125-year-olds are today's 30-year-olds.)

## Implications of the New Demography

It takes time to grow old. If the scythe of death were stayed tomorrow, it would still take a century before there would be many 200-year-olds. Thus, society will have time to adjust to even the most dramatic breakthroughs against mortality. 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.[8] Three issues deserve highlighting.

First, will increases in life expectancy be accompanied by increases in healthy, productive lives? A society in which aging is slowed, so that centenarians are as healthy as 50-year-olds are today, would have great opportunities. A society in which a third of the population requires intensive care would be enormously burdened. The evidence is weak and mixed on morbidity and disability trends in old age[9]; more research is needed.

Second, if the span of healthy life does increase, many people may wish to work longer. In any case, as the number of retired persons grows relative to the number of people of working age, the financial burdens of supporting the retired will force retirement ages upward even more than is occurring already. If older persons hang on to their jobs, however, promotional opportunities will diminish for the young. A major challenge for policymakers will be to help facilitate the development of career patterns that enable the elderly to productively contribute, while simultaneously giving the young a chance. These dilemmas have already been recognized; a new view of life expectancy makes them more troublesome.

Finally, what kind of education should be offered to a person who has to work and keep amused for a century or more? In particular, what should Anna study? She needs an education that en-

ables her to keep learning because society and technology will change radically over her long lifetime. In addition, she would probably benefit from a solid grounding in the liberal arts—in music, the arts, literature, history, the great books of philosophy and science. This background helps a person maintain an active interest in life and is more readily acquired in youth than in old age. In any case, society should invest heavily in the education of a person who may be a member of society for a century or more.

There is some evidence that the growth of the elderly population in the U.S., and the concomitant shift in political power, has reallocated social resources away from children and toward the elderly.[10] It would be ironic if further progress against mortality, by further shifting the age structure, were to result in a parochial focus on the current elderly that would stunt the education and subsequent happiness and productivity of today's children. The latter have very long futures ahead of them, including decades of life beyond age 65.

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**NOTES**

1. For detailed calculations, see Owen, J. M., and Vaupel, J. W., "Anna's Life Expectancy," Working Paper 85-11, International Institute for Applied Systems Analysis, Laxenburg, Austria, Mar. 1985.
2. Faber, J. F., "Life Tables for the United States: 1900–2050," Actuarial Study No. 87, U.S. Department of Health and Human Services Pub. No. 11-11534, 1982.
3. The difference between this figure at 102 and the 90-year estimate produced by extrapolating the age-specific annual rates of progress in the 1970s comes from unevenness of the age-specific rates of progress: although these actual rates averaged 2%, they tended to be greater than 2% at younger ages but less than 2% at the older ages when death most often strikes.
4. This figure is lower than the 90-year estimate produced by simply projecting mortality rates from all causes combined. Under this approach, the causes of death against which little progress is being made become more important as progress is made against other causes of death, reducing the overall advance. The overall rate of progress against mortality, which is the weighted average of the rates of progress being made against specific causes, declines toward the rate of progress being made against the most recalcitrant causes of death. Hence, calculations based on a breakdown of mortality by cause result in a steadily declining overall rate of progress against mortality, even if the rate of progress being made against any particular cause is constant.
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