LONGEVITY AS AN ARTIFACT OF CIVILIZATION

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INTRODUCTION

The populations of most of the nations of the world are growing older. This shift is creating a new demography, a demography of low fertility and long lives. The rapidly growing aging populations are putting unprecedented stresses on societies, because new systems of financial support, social support, and health care have to be developed and implemented. A century ago most of the people born around the world died before they had children; most of the people who had children died before their children had children. Old people were unusual; extended, three-generation families represented only a small fraction of all families. Today, in developed countries and many developing countries as well, the typical newborn can expect to survive to see the birth not only of children and grandchildren but great-grandchildren as well.

I will touch briefly today on some of the health, social, and economic issues arising from the rapid growth in the numbers of older people and the shift of the age-distribution of populations to older age. I cannot even start, however, to do justice to all the interesting research demographers have done on the problems and opportunities associated with population aging. So I would like to focus my talk on a particular aspect of research, namely demographic analyses of survival and longevity.

RAPID GROWTH OF THE OLDER POPULATION

In countries where reliable data are available on centenarians, their numbers are increasing at an exceptionally rapid rate, about 8 percent per year on average. Demographers are used to population growth rates around 1 percent per year; an 8

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percent growth rate seems more like an inflation rate. In England and Wales, an average of 74 persons per year reached age 100 between 1911 and 1920; by 1990 the number of people celebrating their 100^{th} birthday had increased to almost 2000 and in 1997 the number will be around 3000 (Vaupel and Jeune 1995). Zeng Yi and I estimate that the number of centenarians in China is doubling every decade. In 1990 there were about 6000 people age 100 and above in China. By the year 2000 there may be more than 12,000. The population of centenarians is growing, in part, because of the increase in births a century ago, the sharp decline in infant and childhood mortality, and the substantial decline in mortality from childhood up to age 80. Demographic analysis demonstrates, however, that by far the most important factor in the explosion of the centenarian population—two or three times more important than all the other factors combined— has been the decline in mortality after age 80 (Vaupel and Jeune 1995).

Increases in maximum human longevity are also largely attributable to improvements in survival at the highest ages. Lundström (1995) carefully verified the ages of the oldest people who died in Sweden from 1860 through 1994. In the 30 years between 1860 and 1889, no one survived to age 106. Over successive decades, the maximum gradually rose, with the current Swedish record holder having died at age 112 in 1994. As argued by Jeune (1995), it is possible in Sweden (and other countries with modest populations) that no one attained the age of 100 before 1800.

There may have been a few scattered centenarians in earlier centuries, perhaps one per century somewhere in the world, perhaps even fewer (Wilmoth 1995). Zhao Zhongwei (1995) presents some evidence, from his study of the genealogy of the Wang family in China, of a man, Wang Xinglian, who may have died at age 102 in the year 1513. Tan Qihua, on the other hand, in research that has not yet been published, found no plausible examples of centenarians among 4362 famous Chinese who died before 1900 and who are listed in the *Dictionary of Historical Chinese Figures*. In contrast to the very rare sightings of plausible centenarians in past centuries, fully 100,000 genuine centenarians around the world may be alive to welcome the year 2000 (Vaupel 1994).

Wilmoth's (1995) analysis indicates that "there were almost certainly no true super-centenarians (individuals aged 110 or above) prior to the mortality decline of the past two or three centuries." Research by Peter Laslett and colleagues suggest that the first reasonably-well-documented case of a super-centenarian is Katherine Plunket, who died at the age of 111 in 1932 (Jeune 1995). Jeanne Calment is the first carefully-verified instance of a person reaching age 120 (Allard, Lebre, Robine 1994); she died at the age of 122 years and 5 months in August 1997.

Centenarians are still unusual and super-centenarians are a thousand-fold rarer, but these findings do illustrate the fact that mortality reduction can have a major impact on population growth at older ages and on extending the frontier of survival. The growth of the population of female octogenarians in England and Wales provides another telling example. The remaining life expectancy of 80-year-old females in England and Wales around 1950 was approximately 6 years. Currently, the corresponding figure is about 9 years, some 50 percent higher. As a result, the population of female octogenarians in England and Wales is roughly half again as big as it would have been if mortality *after age 80* had remained at 1950 levels. Putting this in terms of the population count, more than a half million females age 80+ are alive today in England and Wales who would have been dead if mortality after age 80 had not been reduced.*

Table 1 provides information about the size of the older population of various countries, from age 60 and up, for both sexes combined. Estimates are also given for the size of these populations in 2025. The projections assume slow improvements in mortality, so I believe that the estimates for 2025 are likely to be low. Nonetheless, the size of the older population shows substantial increases, not only in Europe but in Japan, the U.S., China, and India as well.

Table 1. Proportion of Population above Age 60 (in %) and Population above Age 60 (in millions) for Selected Countries in 1996 and Projected for 2025.

	% 60+		**Millions 60+**	
	1996	**2025**	**1996**	**2025**
Italy	22	33	13	18
Japan	21	33	26	40
Germany	21	32	7	28
France	20	30	12	18
U.K.	21	29	12	17
U.S.A.	17	25	44	83
China	9	20	115	290
Brazil	7	16	11	31
Mexico	7	13	6	18
India	7	12	62	165
South Africa	7	10	3	6
Egypt	6	10	4	10

Source: U.S. Bureau of the Census (1997).

Zeng Yi, Wang Zhenglian and I have recently completed some research on the growth of the old and very old populations in China, up to the year 2050 (Zeng, Vaupel, Wang 1997). Under our low-mortality scenario, which I think may capture the decline in death rates in the future, we estimate that the 65+ year-old population of China will grow from 63 million in 1990 to more than 400 million in 2050, a 6-fold increase. For the 85+ population, we estimate growth from 2.3 million in 1990 to more than 80 million in 2050, an extraordinary 36-fold explosion. By the middle of the next century, then, the oldest-old population, age 85 and older in China may exceed the total population of Germany.

IMPROVEMENTS IN SURVIVAL

Why is the frontier of survival advancing to higher and higher ages? Why are the numbers of the older population growing so rapidly? The answer is that longevity is an artifact of civilization. It is often stated that there is a fixed maximum human life span and this span is determined by our genetic makeup. It is claimed that death rates at advanced ages are the same today as they were in ancient and even prehistoric times (Fries and Crapo 1981). The truth is that death rates at even the most advanced ages are plastic and can be reduced by environmental, behavioral, and medical interventions. There is no evidence that there is a fixed maximum life span. Instead, there is compelling evidence that over the past 50 years remarkable improvements have been made in increasing survival at older ages.

Despite the evidence, many people still believe that old-age mortality is intractable. Because of its implications for social, health, and research policy, the belief is pernicious; forecasts of the growth of the elderly population, expenditures on life-saving health care for the elderly, and expenditures for biomedical research on the deadly illnesses of old age are all too low.

Far from being intractable, mortality at older ages has fallen dramatically since 1950 in developed countries and most developing countries as well. Tables 2 and 3 present a few figures, but extensive documentation is available elsewhere (Kannisto 1994, 1996; Kannisto et al. 1994; Vaupel et al. 1998).

Table 2 shows the rates of improvement in female mortality at older ages in the Nordic countries of Denmark, Finland, Norway, and Sweden. These countries have exceptionally reliable data up to the highest ages. The rate of improvement is impressive, especially since the 1960s. Also striking is the acceleration of mortality improvement over time. Male death rates are higher than female rates at all ages from conception to advanced old age. Male rates of mortality improvement have been slower than female rates. But substantial gains have also been made for males in recent decades.

Table 2. Average annual rate of improvement in female mortality (in %) for aggregation of Denmark, Finland, Norway and Sweden, for sexagenarians, septuagenarians, octogenarians, and nonagenarians, over successive 20-year periods.

	Age Category			
Time Period	**60s**	**70s**	**80s**	**90s**
1900s-1920s	0.3	0.2	0.1	0.0
1920s-1940s	0.7	0.4	0.2	0.0
1940s-1960s	1.7	1.0	0.6	0.5
1960s-1980s	1.5	2.1	1.7	1.2

Source: Own calculations. See Kannisto et al. (1994) for description of data and of how average annual rates of improvement are calculated.

Table 3 displays death rates by age and time for females in the Nordic countries. The increase in death rates with age is dramatic. The decrease in death rates over time is also noteworthy. If mortality is reduced, then the number of lives saved is proportional to the absolute decline rather than the relative decline. For instance, if the probability of death at a particular age is reduced from 20 percent to 15 percent, then an extra 5 percent of the population continue to enjoy life. In the last row of Table 3, the absolute improvements in Nordic female mortality are displayed. It is at the most advanced ages that the most lifesaving has occurred. On second thought, this may not seem so surprising because it is at the highest ages that death rates are very high. Moreover, lives saved at the highest ages are generally not extended for more than a few years. Nonetheless, the large absolute reductions in mortality among centenarians and nonagenarians is a remarkable achievement, at sharp variance with the view that old-age mortality is intractable.

Table 3. Female central death rates (in %) for aggregation of Denmark, Finland, Norway and Sweden for sexagenarians, septuagenarians, octogenarians, nonagenarians, and centenarians, in two periods, 1930-49 and 1989-1993.

Age:	**60s**	**70s**	**80s**	**90s**	**100s**
Time Period					
1930-49	2.4	6.4	16.1	33.9	70.1
1989-93	1.1	3.1	9.1	23.4	48.5
Variance	1.3	3.3	7.0	10.5	21.6

Source: Own calculations. See Kannisto et al. (1994) for description of data and of how average annual rates of improvement are calculated.

VARIATION IN LIFE SPAN

The multiplication of the population of older people heightens interest in a fundamental question: Why do some people die at 60, others at 80, and a few at 100? Why are the odds of dying at 80 rather than 60 increasing and the chance of surviving to 100 rapidly increasing (albeit from a very low level)? How important are genetic versus environmental, behavioral, and medical factors in determining how long an individual will live?

It might be expected that the answers to these questions—and the determinants of longevity more generally—are well understood. The duration of life has captured the attention of people for thousands of years. The life span for humans as well as for other species can be readily measured. Many countries have a huge array of statistical data going back for many centuries.

A recent review, however, of the determinants of longevity (Christensen and Vaupel 1996) concludes that surprisingly little is known. The chance of reaching age 80 (or 90 or 100) is better for:

- women than men
- people born in this century rather than earlier
- people born in developed countries, and
- people who have favorable genes, such as the ApoE 2 gene (Schächter et al. 1994).

Smoking is certainly a health hazard for young and old. Obesity may be a risk factor and diet is probably important. Some pharmaceuticals, such as DHEA, may increase survival at older ages. Studies of twins and other related individuals suggest that about 25 percent of the variation in adult life expectancy appears to be attributable to genetic variation among individuals (McGue et al. 1993, Herskind et al. 1996). Research in progress by Anatoli Yashin and Ivan Iachine suggests that an additional 25 percent may be attributable to non-genetic characteristics that are more or less fixed by the time a person is about 30: characteristics such as educational achievement, socioeconomic status, parents' ages at a person's birth, etc. Research on the relative importance for longevity of various candidate genes and non-genetic fixed attributes is, however, still at an early stage of development.

Barker's (1992, 1995) "fetal-origins hypothesis" suggests that nourishment *in utero* and during infancy, programs the development of risk factors for several important diseases of middle and old age. Other researchers have also concluded that nutrition and infections early in life have major effects on adult mortality (Kermack, McKendrick, McKinlay 1934, Elo and Preston 1992, Fogel 1993). To the extent this is true, longevity may be determined by conditions in childhood and, perhaps, even before birth. There is, however, conflicting evidence to suggest that current conditions (i.e., at older ages) may be much more important than conditions early in life. Kannisto (1994, 1996) finds period effects to be much more important than cohort effects on mortality after age 80. Christensen et al. (1995) find that from age 6 up to the oldest ages, twins (who tend to be born prematurely and at low birth weight) suffer the same age-specific death rates as singletons. And Kannisto, Christensen, and Vaupel (1997) find "no increased mortality in later life for cohorts born during famine." Pinning down the nature and magnitude of possible lingering effects of early-life conditions on survival at advanced ages is an important research priority.

CONCLUSION

Over the past half century and especially in the most recent decades, remarkable improvements have been achieved in survival at older ages, especially at the highest ages. This progress has accelerated the growth of the population of older people and has advanced the frontier of human survival substantially beyond the extremes of longevity attained in pre-industrial times.

Little, however, is yet known about why mortality among the oldest-old has been so plastic since 1950. There is considerable (but still inadequate) knowledge of why some people die in infancy or childhood and why some people die prematurely at adult ages before age 60 or 70. Much less is known about why some people survive to age 80, others to age 90, and a few to age 100. The little that is known has largely been learned within the past few years and new findings (especially concerning genetic factors) are emerging at a rapid rate.

Although we do not yet know the causes of the remarkable improvements in old-age survival, we do know that they have occurred and that mortality, even at advanced ages, is highly changeable. The intractability of mortality at older ages is untenable. Genetic factors play some role in how long a person lives; non-genetic factors play an even more important role. The progress made since 1950 in reducing mortality at older ages is entirely attributable to non-genetic changes. Longevity is an artifact of civilization, one of the towering achievements of modern life.

Endnote

* The figure of 9 years for the remaining life expectancy of 80-year-old females in England and Wales is an estimate for 1997, based on data from Kannisto (1996). It is not a precise figure, but good enough for illustrative purposes. Change in life expectancy is often (but not always) serviceable as a rough indicator of the impact of mortality reductions on population size; the required calculations to produce a more exact estimate are fairly complicated. See Kannisto (1996) or Vaupel and Jeune (1995) for details. Kannisto's calculations indicate that mortality improvements after age 80 in England and Wales between 1960 and 1990 (rather than 1950 and 1997) increased the female population by 250,000 persons.

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