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Author(s): S. Jay Olshansky and A. Brian Ault

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# The Fourth Stage of the Epidemiologic Transition: The Age of Delayed Degenerative Diseases

S. JAY OLSHANSKY and A. BRIAN AULT

*Argonne National Laboratory;  
Child Trends, Inc.*

SINCE THE TURN OF THE CENTURY IN THE UNITED States life expectancy at birth has increased from 47.0, to 73.6 in 1980. To gain a perspective of the magnitude and timing of this increase, it is estimated that it took the previous 2,000 years to achieve a comparable increase for the entire human species (Dublin, Lotka, and Spiegelman 1949, 26–43). The cause of the rapid increase in life expectancy in this century was a substitution of degenerative causes of death such as heart disease and cancer for deaths that were previously caused by infectious and parasitic diseases. This shift in disease patterns has been referred to as the epidemiologic transition (Omran 1971).

According to the theory of the epidemiologic transition, as nations modernize they tend to improve their social, economic, and health conditions. Life conditions that were previously conducive to the spread of infectious and parasitic diseases are rapidly replaced by more sanitary living conditions, improved medical technology, and better lifestyles. As the risk of dying from infectious diseases is reduced for a population, those saved from dying from such diseases survive into middle and older ages where they face the elevated risk of dying from “degenerative or man-made diseases.” Since degenerative diseases tend

to kill at much older ages than infectious diseases, this transition in causes of death is characterized generally by a redistribution of deaths from the young to the old.

The epidemiologic transition theory, as it was originally set forth, was designed to provide a general picture of the major determinants of death that prevailed during several distinct periods in our epidemiologic history. In order to set forth the general characteristics of what is described in this paper as the fourth stage of the epidemiologic transition, it is necessary to define more precisely the components that make up each stage of the transition. As a way of reconceptualizing the epidemiologic transition theory, it is appropriate to identify three basic components of epidemiologic change that distinguish one stage from another.

The first component was identified originally by Omran (1971) as shifts in recorded cause-of-death patterns. Trends in causes of death are observed most frequently as a ratio of the relative contributions of each cause of death to deaths from all causes, or more simply as changes in the relative rankings of the ten leading causes of death. Rapid changes in cause-of-death patterns imply that a major transition in the general health status of the population has taken place.

The second component involves the age and sex groups of the population that are affected by mortality transitions. The importance of following changes in patterns of death among different age and sex groups is that one may determine, first, whether some subgroups of the population are benefiting more or less than others from changes in the population's general health status, and second, it provides more detailed information on the relative risk of death by cause for population subgroups.

The third component of epidemiologic change is the effects of transitions in causes of death on survival. Here we ask the fundamental question: Who benefits the most from mortality transitions in terms of gains in life expectancy? The importance of this component is that it identifies the benefactors of declining mortality not just in terms of changes in the risk of dying, but in terms of a concept that is understood more easily—the number of years of life gained. Also, by observing relative changes in longevity for different age and sex groups as a function of mortality change across the age structure, it is possible to pinpoint where the largest gains in longevity are concentrated.

If we evaluate the first stage of the epidemiologic transition (The Age of Pestilence and Famine) using these three components, we note first that this stage is characterized not by changes in average death rates but by a stagnation of death rates at extremely high levels for a period of what is believed to be thousands of years. During this stage, death rates fluctuated at very high levels between peaks and troughs in response to epidemics (i.e., infectious and parasitic diseases) that periodically ravaged the population. The major killers during this era included influenza, pneumonia, diarrhea, smallpox, tuberculosis, and other related diseases. Infants and children were preyed upon the most by the major killers of this era, although women of reproductive ages also faced an unusually high risk because of the complications associated with pregnancy and delivery. Since the major causes of death during this time tended to take their greatest toll on the young, the effects on survival are profound in that the median age at death is skewed heavily toward younger ages, and life expectancy hovers somewhere between 20 and 40.

The second stage (The Age of Receding Pandemics) is noted as a transitional phase and is characterized most by rapid changes in the components of our epidemiologic history. During this stage, the peaks and troughs of mortality were smoothed out initially by rapid improvements in sanitation and standards of living, with medical and public health measures contributing significantly after midcentury (McKinlay and McKinlay 1977; Chen and Wagner 1978). With health and social conditions improving, those who would have previously succumbed to infectious and parasitic diseases survive through their early years into middle and older ages where they face the elevated risk of dying from chronic degenerative diseases. Since degenerative diseases and infectious and parasitic diseases tend to kill at opposite ends of the age structure, the transformation in causes of death during this era resulted in a redistribution of death from the young to the old. The most favorable effects on survival were, therefore, concentrated among infants, children, and women of childbearing ages, which resulted in increased prospects for surviving to and through adulthood. During this stage, life expectancy at birth increased to about 50 years of age.

The third stage (The Age of Degenerative and Man-made Diseases) has been described basically as a plateau phase in our epidemiologic

history where we again reach a level of equilibrium in mortality, but at a level considerably lower than that of the first stage. In this stage the pace of the declines in mortality rates throughout the age structure slows as the theoretical limits to mortality declines are approached. The major causes of death for the population are established as chronic degenerative diseases, such as heart disease, cancer, and stroke, which tend to kill at ages near what was believed to be the end of the life span. The effect on longevity is a life expectancy for the population that reaches into seven decades of life and which was expected to change little in the future.

At the time this general theory of mortality change was published in 1971, there was reason to believe that mortality declines had bottomed out and gains in life expectancy from that time forward would progress at a snail's pace. The rationale for that belief was that there had to be limits to declining mortality as the biological limit to life is approached, and it was generally believed at the time that seven decades of life was close to that limit.

A few years prior to the publication of the epidemiologic transition theory, the United States and other developed nations began to experience unexpectedly rapid declines in mortality rates for the major degenerative diseases. In the United States, for example, heart disease declined by more than 25 percent between 1968 and 1978 (U.S. Department of Health and Human Services 1981), and there is evidence to indicate that such declines have continued and are expected to continue into the future (Gillum, Folsom, and Blackburn 1984; Havlick and Feinleib 1979). Death rates for other degenerative diseases such as cancer and stroke have also declined since the early 1970s (U.S. Department of Health and Human Services 1980; 1982). While the greatest benefits of these declining death rates were experienced first by the population passing through their middle ages, today some of the largest declines are occurring among those from whom one might least expect them—cohorts recently passing through advanced ages. Furthermore, data on international trends in cause-specific mortality indicate that the majority of the declining age-specific death rates are occurring as a result of declining mortality for major cardio-vascular diseases. The timing of this new trend is known to have begun in the mid-1960s (Pisa and Uemura 1982; Uemura and Pisa 1985; Rosenwaike, Yaffe, and Sagi 1980). A 25 percent decline in the nation's number one cause of death within a ten-year time period is a remarkable achievement

cause of death within a ten-year time period is a remarkable achievement in itself, but when it occurs for a degenerative disease among the population in advanced ages, it may be considered a major achievement in our epidemiologic history.

This unanticipated decline in death rates from degenerative diseases raises two important questions. First, why did this transition begin at that particular time in our epidemiologic history—in the mid-1960s, and just after it appeared that mortality rates had reached a lower plateau? And second, what precipitated this new stage and what is currently sustaining the continuation of this phase today?

In answering these questions, it is possible to identify several historical circumstances that are generally believed to have contributed to this new era in our epidemiologic history. First, the mortality transition that occurred during “The Age of Receding Pandemics” created a fundamental change in the prospects for survival and in the age structure of the United States population. From a historical perspective we were literally transformed overnight from a relatively young population with a broadly based age structure through the mid-nineteenth century, into a rapidly aging population. Within just fifty years from the turn of the century the median age of the United States population had increased from 22.9 to 30.2, and the proportion of the total population aged 65 and over had increased from 4.1 percent to 8.1 percent (U.S. Bureau of the Census 1975). This fundamental change in the age structure, with rapidly increasing proportions of successive birth cohorts surviving into advanced ages, literally created an entirely new segment of the population with unique health care needs and demands that were tied to chronic degenerative diseases and age-associated physiological impairments.

Moreover, by the second half of the twentieth century, significant declines in infant and child mortality had largely been achieved for the majority of the United States population, and the health care community began to focus its attention more on the chronic degenerative conditions that plagued the survivors into advanced ages. With the development of new drugs and antibiotics and improved methods of diagnosing and treating degenerative diseases and their complications, the health care community became increasingly successful in postponing deaths from degenerative diseases by slowing the rate of chronic disease progression and by reducing case-fatality rates (U.S. Department of Health and Human Services 1980; Watkins 1984; Manton 1982).

And finally, advances in medical technology were also accompanied by reductions in some major risk factors for degenerative diseases (on a population scale) such as declines in smoking, more exercise, and improved dietary habits (Havlick and Feinleib 1979; Walker 1977; Watkins 1984; Gillum, Folsom, and Blackburn 1984). Moreover, federal health care programs that began in the 1960s were targeted primarily at the elderly and poor segments of the population, and are thought to have contributed to mortality declines by reducing inequities in access to quality health care.

The combination of all of these factors—improved survival and a pronounced shift in the age structure toward older ages, recent advances in medical technology and public health measures that favored the old over the young, federal health care programs that favored the elderly and poor, and reductions in risk factors on a population scale—are largely responsible for this new era in our epidemiologic history. However, the relative contributions of each of these circumstances to declining mortality has yet to be determined. In effect, prospects for improved survival were then largely concentrated among those segments of the population that were increasing the fastest both in terms of absolute numbers and proportions—cohorts passing through advanced ages—thus leading to rapid declines in death rates from major degenerative diseases on a population scale.

As a result of this unexpected transition among degenerative diseases, the expectation of life at birth in the United States has risen rapidly in recent years to the upper end of the seventh decade of life, and among some populations in the developed world, life expectancy has already reached eight decades. It is generally recognized now that life expectancy for some developed nations will reach well into the eighth decade by the turn of the century. More interestingly, however, such gains in longevity have been, and are likely to continue to be propelled into eight decades by unprecedented and significant mortality declines among the cohorts that will reach advanced ages in the coming decades (Myers 1983).

It is suggested in this paper that the timing and magnitude of this mortality transition is significant and distinct enough from the previous three stages to qualify as the fourth stage of the epidemiologic transition. The general characteristics of the fourth stage include: (1) rapidly declining death rates that are concentrated mostly in advanced ages and which occur at nearly the same pace for males and females; (2) the age pattern of mortality by cause remains largely the same as in

the third stage, but the age distribution of deaths for degenerative causes are shifted progressively toward older ages; and (3) relatively rapid improvements in survival are concentrated among the population in advanced ages. Thus, in this stage the major degenerative causes of death that prevailed during the third stage of the transition remain with us as the major killers, but the risk of dying from these diseases is redistributed to older ages. This unexpected shift in the age pattern of mortality for degenerative causes for the population in advanced ages is what is so unique about the fourth stage and is its major distinguishing characteristic from the third stage of the transition. Since this stage is characterized most by a substitution of the ages at which the major determinants of death prevailing at the time tend to kill, this stage in our epidemiologic history will be referred to as "The Age of Delayed Degenerative Diseases." We will use mortality data from the United States to illustrate the timing and magnitude of this fourth stage.

## The United States Experience

As a result of the epidemiologic transition, today in the United States approximately three of every four deaths occur as a result of degenerative diseases, primarily in advanced ages. We have achieved such remarkable success in reducing death rates in younger and middle ages that now there is relatively little room left for improvement barring the reduction of accidents, homicide, and suicide. This means that if *significant* mortality declines and gains in life expectancy are to be achieved in the future, they will have to occur as a result of achievements made at older ages.

Recent data suggest, in fact, that older generations throughout the developed world have achieved some remarkable declines in mortality and gains in life expectancy in advanced ages (Manton 1984; Lopez and Hanada 1982). In fact, recent research on mortality patterns in advanced ages for the United States indicate that significant mortality declines are occurring in every age group beyond the age of 65 (Crimmins 1984; U.S. Department of Health and Human Services 1984). Mortality declines of this magnitude in advanced ages are considered remarkable because it is believed that as a population we are now rapidly approaching the biological limit to life and it takes



increasingly larger investments from the health care industry to achieve even small returns as gains in life expectancy. The issue of determining the age of the biological limit to life, however, is not without debate as we may note from recent articles on this topic (Myers and Manton 1984; Fries 1984). Moreover, it is questionable as to how long we may successfully reap longevity benefits from improving risk factors and delaying degenerative causes of death into advanced ages.

In the sections that follow, we will analyze complete life tables by decade for males and females in the United States from 1900 to 1980, and projected complete life tables to the year 2020. The life tables were published by the U.S. Office of the Actuary (Faber 1982). Mortality projections were performed by analyzing average annual improvements in central death rates by age, sex, and ten leading causes of death for the period 1968 to 1978, and extrapolating these trends forward in time based upon assumptions of how such factors as advances in research, environmental pollution, incidence of violence, continued improvements in lifestyles, personal responsibility for health care, etc., might influence mortality. Mortality counts published by the National Center for Health Statistics (1963, 1974, 1985) are also used in this analysis.

The timing and magnitude of the fourth stage of the epidemiologic transition will be illustrated by examining trends in life expectancy, temporary life expectancies (to be described shortly), survival curves, a decomposition of changes in temporary life expectancies into the relative contributions of mortality change made by selected age ranges, and recent shifts in the age distributions of death for selected degenerative diseases.

### *Life Expectancy*

Table 1 records life expectancy at selected ages for the United States observed from 1900 to 1980, and projected to the year 2020 based upon estimates made by the U.S. Office of the Actuary. Two notable patterns emerge. First, in the early part of this century the largest absolute and percentage increases in life expectancy occurred in younger age groups. For example, from 1900 to 1920 females gained 7.3 years (14.8 percent) at birth and only .13 years (3.3 percent) at age 85. By the end of this century the U.S. Office of the Actuary projects a slowdown in gains in life expectancy at birth and relatively rapid

TABLE 1  
Observed (1900–1980) and Projected (1990–2020) Life Expectancy at Selected Exact Ages in the United States, by Sex

Ages	Projected												
	1900 (1)	1910 (2)	1920 (3)	1930 (4)	1940 (5)	1950 (6)	1960 (7)	1970 (8)	1980 (9)	1990 (10)	2000 (11)	2010 (12)	2020 (13)
Males													
0	46.56	50.20	54.59	58.01	60.89	65.33	66.58	67.05	69.85	72.29	73.42	73.93	74.42
20	41.73	42.63	44.45	45.14	46.77	49.01	49.65	49.64	51.64	53.71	54.76	55.23	55.68
40	27.52	27.64	29.20	28.82	29.42	30.87	31.32	31.56	33.42	35.26	36.20	36.67	37.12
60	14.18	14.18	14.87	14.69	14.84	15.75	15.86	16.11	17.29	18.55	19.24	19.64	20.03
85	3.73	3.88	3.95	4.12	4.05	4.49	4.61	4.74	5.08	5.63	6.00	6.23	6.47
Females													
0	49.07	53.67	56.33	61.36	65.34	70.90	73.19	74.80	77.53	79.85	81.05	81.62	82.18
20	42.90	44.98	44.83	47.51	50.24	53.86	55.62	56.82	58.90	60.94	62.06	62.60	63.13
40	28.69	29.57	30.06	31.01	32.54	35.19	36.64	37.87	39.69	41.58	42.65	43.18	43.70
60	14.96	15.16	15.48	16.04	16.78	18.61	19.57	20.88	22.20	23.79	24.70	25.19	25.66
85	4.00	4.06	4.13	4.41	4.36	4.98	5.11	5.72	6.32	7.23	7.82	8.13	8.44

Source: Faber 1982.

gains in longevity in advanced ages. Over the 40-year time period from the year 1980 to 2020, for instance, absolute and percentage increases in life expectancy for females are projected to be 2.12 years (33.5 percent) at age 85 and 4.65 years (6.0 percent) at age zero, respectively. Similar patterns are projected for males. This represents a complete reversal of trends in mortality and life expectancy where gains that previously occurred in younger ages are now replaced by relatively large increases in life expectancy in advanced ages.

Also, sex differences in life expectancy at birth have increased steadily from 1900 until the decade of the 1970s (except for a brief time period during the influenza epidemic in 1918). They are then projected to decrease by 1990 and then increase to the difference that was observed in 1970. Although explanations for these sex differences in life expectancy are complex, it is important to note that the historical pattern of a widening gap in longevity between the sexes is projected to come to an end during the fourth stage of the epidemiologic transition in the United States. Whether this trend will hold true for other developed nations has yet to be determined.

### *Temporary Life Expectancies*

Table 2 records observed and projected changes in temporary life expectancies at selected ages for males and females. A temporary life expectancy (TLE) may be interpreted as the average number of years that a group of persons at exact age  $x$  will live from age  $x$  to  $x + i$ . The temporary life expectancy from birth to age 85, for example, is considered a more reliable measure of changes in life expectancy at birth than using  $e_x^0$  because it avoids problems of data reliability at older ages. The calculation of TLEs also provides an estimate of the relative changes occurring in life expectancy within selected age ranges that occur as a result of mortality change in age groups within those age ranges (Arriaga 1984).

For example, a figure of 46.38 for males in 1900 at age interval "birth to age 85" means that male babies born in 1900 could expect to live an average of 46.38 years if they experienced the mortality rates of the period in which they were born, throughout their lives. The figure of 24.76 for females in 1980 at age interval 20 to 45 means that for those who reached their 20th birthday in 1980, they could expect to live an average of 24.76 out of a possible 25 years

TABLE 2  
Observed (1900–1980) and Projected (1990–2020) Changes in Temporary Life Expectancies at Selected Exact Age Intervals for the  
United States, by Sex

Ages	1900 (1)	1910 (2)	1920 (3)	1930 (4)	1940 (5)	1950 (6)	1960 (7)	1970 (8)	1980 (9)	Projected			
										1990 (10)	2000 (11)	2010 (12)	2020 (13)
Birth to age 85													
Males	46.38	50.00	54.32	57.70	60.55	64.80	66.00	66.41	68.96	71.02	71.91	72.27	72.60
Females	48.82	53.37	55.99	60.88	64.75	69.85	71.92	73.05	75.15	76.58	77.22	77.50	77.76
Birth to age 20													
Males	15.62	16.48	17.39	18.13	18.45	19.08	19.24	19.40	19.62	19.71	19.73	19.75	19.76
Females	16.15	16.95	17.80	18.47	18.78	19.29	19.43	19.54	19.71	19.78	19.80	19.81	19.82
Ages 20–45													
Males	22.62	22.95	23.14	23.54	23.97	24.29	24.37	24.28	24.35	24.46	24.50	24.51	24.52
Females	22.69	23.21	22.98	23.68	24.18	24.56	24.67	24.67	24.76	24.81	24.82	24.83	24.83
Ages 45–65													
Males	16.80	16.85	17.32	17.15	17.32	17.64	17.77	17.82	18.23	18.55	18.69	18.74	18.78
Females	17.09	17.41	17.52	17.70	18.10	18.54	18.78	18.82	19.04	19.19	19.26	19.29	19.32
Ages 65–85													
Males	10.87	10.88	11.25	11.22	11.31	11.94	12.00	12.14	12.76	13.42	13.76	13.95	14.14
Females	11.41	11.47	11.67	12.07	12.52	13.65	14.26	14.92	15.50	16.11	16.40	16.55	16.69

Source: Calculated from data published by Faber (1982).

in the age interval. If the TLE for the age interval was 25, then virtually everyone who reached their 20th birthday would also be assured of reaching their 45th birthday (i.e., zero deaths in the age interval).

According to these data, TLEs increased rapidly throughout this century in all age groups and for almost all time periods (excluding 1920 to 1930 for males aged 45 and older, females aged 20 to 45 from 1910 to 1920, and males aged 20 to 45 from 1960 to 1970). The largest absolute increases within age ranges occurred in the earlier part of this century, with smaller increases projected to occur by the year 2020. Note that in the two youngest age intervals (0 to 20 and 20 to 45) during this century the TLEs rapidly approach the size of the age interval, thus indicating that mortality is already so low in these age ranges that further improvements will be difficult to achieve. It is for this reason that the magnitude of the increases in TLEs is projected to decrease past 1990, except in the oldest age interval where there is still room and expectation for further improvements.

Basically these data provide one with a clear picture of the magnitude of the potential gains in longevity that remain for the different age-sex groups in the United States. Females in 1980, for example, had less than one-third and one-quarter of a year of life that remained to be achieved within the two younger age intervals, respectively. In the oldest age group in 1980 about 4.5 years remained to be achieved for females. Projections to the year 2020 indicate that the oldest age groups for both males and females will achieve the largest relative increases in TLEs. This illustrates the point that if life expectancy at birth increases in the future it will have to occur primarily as a result of mortality declines in the age groups where there is still room for improvement—older cohorts.

### *Index of Annual Relative Change*

While TLEs are useful they do not provide one with a true picture of the *pace* of the relative gains in longevity over time because absolute gains should be considered in relation to the maximum possible change that may occur (Arriaga 1984). For example, the projected 4.57 and 4.65 year increase in life expectancy at birth for males and females, respectively, from 1980 to 2020 may be interpreted as a 6.5 percent

increase for males and a 6.0 percent increase for females. One might conclude from this that males are expected to make the greater achievement of the two sexes by the year 2020. However, when these projected gains in life expectancy at birth are shown as a proportion of the maximum possible change (let us say the difference between the observed life expectancy and a biological limit to life estimated at 100 years of age), then males would experience a 15.2 percent increase toward the biological limit to life while females would experience a 20.7 percent increase toward the same biological limit to life (using the age of 100 as an illustration of the biological limit to life for males and females). Under this interpretation the greater achievement is now thought to go to females. The same logic may be applied when calculating observed and projected gains in TLEs within selected age ranges. One way to address this issue of relative change in life expectancy is to calculate an index of annual relative change.

Table 3 shows observed and projected indexes of annual relative change in selected TLEs for the United States for the decades from 1900 to 2020. This measure may be interpreted as the annual percentage change in life expectancy within a given age range as a proportion of the maximum possible change. For example, the figure of 3.13 for females in 1970 to 1980 in the age range of 20 to 45 may be interpreted as an annual 3.13 percent increase toward the maximum possible change in the TLE during that decade.

The data in table 3 suggest that while there were some rather dramatic fluctuations in the pace of improvements in TLEs, for the most part the largest gains occurred between 1930 and 1950 across the age structure. The pace of the improvements then declined until 1970 during which they again increased unexpectedly for most age-sex groups. This corresponds with the onset of the rapid declines in coronary heart disease mortality and other degenerative causes of death. This general pattern of fluctuations held true in all age ranges except the oldest, where the pace of relative improvements peaked in the decade of the 1940s, declined in the decade of the 1950s, and then gradually increased again to a peak projected for the decade of the 1980s. Past 1990 the pace of improvements in TLEs in all age ranges was projected to taper off rapidly. In effect, this means that for those who reached the beginning of each age interval during these years, successively larger proportions have been observed to survive, and are

TABLE 3

Observed (1900–1980) and Projected (1990–2020) Index of Annual Relative Change in Selected Exact Temporary Life Expectancies in the United States, by Sex

Ages	1900-1910 (1)	1910-1920 (2)	1920-1930 (3)	1930-1940 (4)	1940-1950 (5)	1950-1960 (6)	1960-1970 (7)	1970-1980 (8)	Projected			
									1980-1990 (9)	1990-2000 (10)	2000-2010 (11)	2010-2020 (12)
Birth to age 85												
Males 0.98		1.31	1.16	1.10	1.89	0.61	0.22	1.46	1.37	0.66	0.28	0.26
Females 1.34		0.86	1.83	1.73	2.86	1.46	0.90	1.91	1.56	0.79	0.37	0.35
Birth to age 20												
Males 2.16		2.95	3.28	1.86	5.08	1.89	2.34	4.46	2.67	0.71	0.77	0.41
Females 2.30		3.21	3.57	2.24	5.27	2.17	2.12	4.51	2.72	0.95	0.51	0.54
Ages 20–45												
Males 1.48		0.97	2.39	3.43	3.65	1.19	– 1.34	1.02	1.84	0.77	0.20	0.21
Females 2.52		– 1.22	4.17	4.65	6.04	2.84	0.00	3.13	2.31	0.54	0.57	0.00
Ages 45–65												
Males 0.16		1.60	– 0.62	0.61	1.26	0.57	0.23	2.06	1.97	1.01	0.39	0.32
Females 1.16		0.43	0.75	1.89	2.60	1.78	0.33	2.04	1.68	0.90	0.41	0.43
Ages 65–85												
Males 0.01		0.41	– 0.03	0.10	0.75	0.07	0.18	0.82	0.95	0.53	0.31	0.32
Females 0.07		0.24	0.49	0.58	1.62	1.00	1.21	1.21	1.45	0.77	0.42	0.41

Source: Calculated from data published by Faber (1982).

projected to survive, to the subsequent age interval. This rapid decline in the pace of improvements in TLEs is expected since the data in table 2 suggest that the TLEs in the younger age groups have rapidly approached the size of the age interval and the limits to further declines.

### *Survival Curves*

A changing pattern of survival during this century among younger vs. older cohorts may be observed from the survival curves in figures 1 and 2. Note that in 1900 there were rapid declines in the survival curves in the first few years of life with rapidly declining infant and child mortality. As the diseases that affect the young were replaced by degenerative diseases, more people survived through their first few years of life into middle and older ages, which subsequently led to a much slower drop-off of the survival curve for both sexes (shown

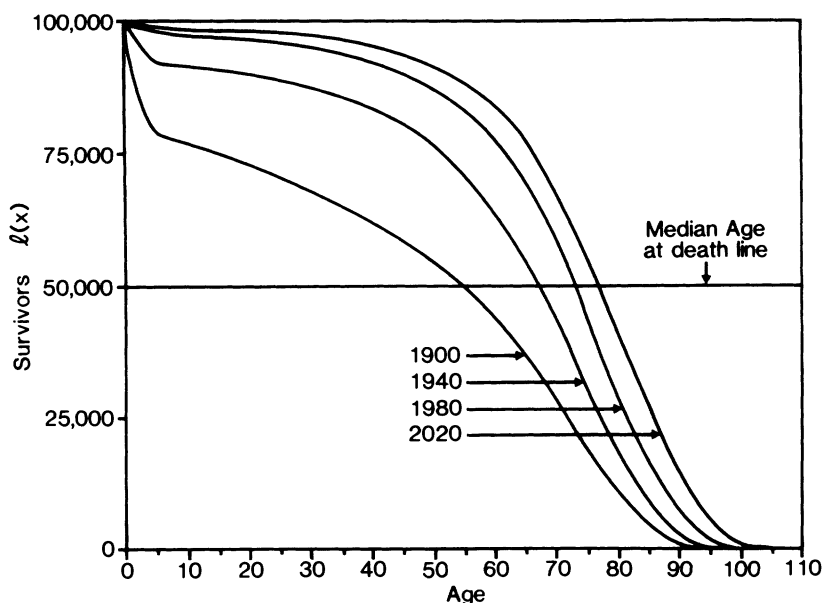


FIG. 1. Survival curves for U.S. males (1900–2020).



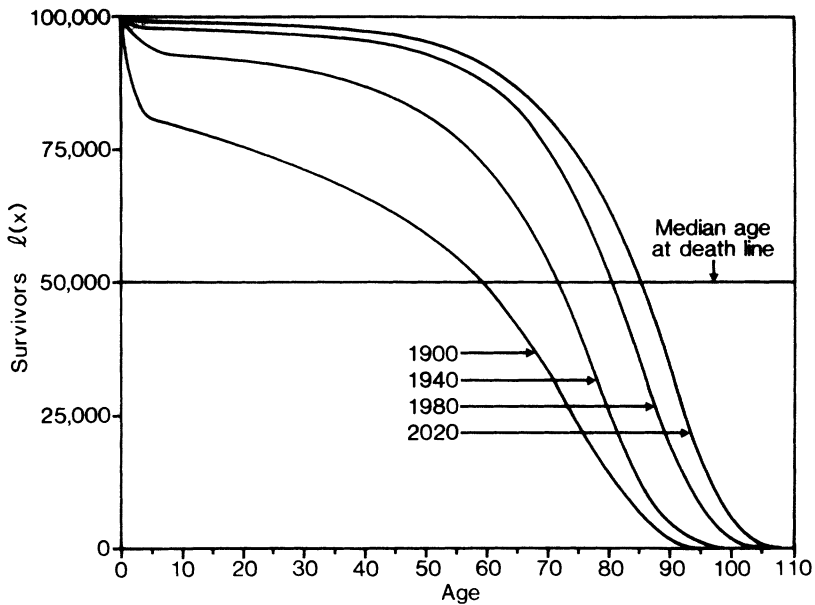


FIG. 2. Survival curves for U.S. females (1900–2020).

here for 1940 and 1980). Projections of survival to the year 2020 illustrate that older generations will gain significantly more than any other part of the age structure. This may be observed by noting that the vertical increase in the survival curve is greater in older ages than in younger ages between 1980 and 2020.

Also, observe how the median age at death is being pushed farther in the direction of older ages so that by the year 2020 half of the birth cohorts for those years are projected to survive to ages 77 and 86, respectively, for males and females (see table 4). In fact, over eight of every ten people born in the year 2020 are projected to survive to their 85th birthday. Since relatively small gains in survival are projected to occur for younger and middle age groups in the coming decades, this shift in the median age at death must necessarily be brought forth by declining mortality in advanced ages. This is a complete reversal of the patterns of improved survival that occurred earlier in this century.

TABLE 4  
Median Age at Death and Proportion Surviving to Ages 65 and 85, by Sex  
(United States, 1900–2020)

Sex	1900 (1)	1940 (2)	1980 (3)	2020 (4)
Median age at death (in years)				
Males	55	67	73	77
Females	58	72	81	86
Proportion surviving to age 65				
Males	37.4	55.0	70.3	78.6
Females	41.1	65.0	83.5	87.8
Proportion surviving to age 85				
Males	4.7	8.2	17.5	28.1
Females	6.2	13.4	37.6	52.4

Source: Calculated from data published by Faber (1982).

### *Contributions to Gains in Longevity*

To best illustrate the recent gains in mortality in advanced ages and the importance of such gains to changes in life expectancy, we should examine the relative contributions to gains in longevity that are made by observed and projected mortality change within selected age ranges. This will serve to illustrate *shifts* in the relative importance of different age groups to observed and projected gains in TLEs during this century.

Table 5 illustrates how mortality patterns during this century have contributed to patterns of change in the TLE from birth to age 85 from 1900 to 1980, and the extent of its contribution in the future based upon U.S. Office of the Actuary projections. According to these data, in the first two decades of this century the mortality change in the youngest age interval (0 to 20) contributed from two-thirds to over three-quarters of the gain in the TLE from birth to age 85 in those decades. For example, of the 3.62 year gain in the TLE for males from 1900 to 1910, 82 percent or 2.97 of those years gained were caused by mortality declines among the population aged 0 to 20. Less than 4 percent of the increase was attributable to mortality change from the oldest age interval (65 to 85) for either sex during these decades. This finding is consistent with the transformation in

TABLE 5

Observed (1900-1980) and Projected (1980-2020) Contribution of the Mortality Changes in Selected Exact Age Groups to the Total Change in Temporary Life Expectancy from Birth to Age 85 in the United States, by Sex.

Ages	Projected											
	1900-1910 (1)	1910-1920 (2)	1920-1930 (3)	1930-1940 (4)	1940-1950 (5)	1950-1960 (6)	1960-1970 (7)	1970-1980 (8)	1980-1990 (9)	1990-2000 (10)	2000-2010 (11)	2010-2020 (12)
MALES												
TLE increase	(3.62)	(4.32)	(3.38)	(2.85)	(4.25)	(1.20)	(0.41)	(2.55)	(2.06)	(0.89)	(0.36)	(0.33)
(in years)												
0-20	82.0	74.7	83.5	50.3	56.3	52.7	114.7	33.5	20.4	11.7	15.4	12.5
20-45	16.7	4.9	25.4	39.6	23.1	24.7	-60.0	14.6	19.7	20.0	9.6	8.8
45-65	1.2	16.5	-8.5	8.5	12.5	19.5	24.6	36.2	37.3	39.6	35.4	34.4
65-85	0.1	3.9	-0.4	1.6	8.1	3.1	20.7	15.7	22.6	28.7	39.6	44.3
All ages	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
FEMALES												
TLE increase	(4.55)	(2.62)	(4.89)	(3.87)	(5.10)	(2.07)	(1.13)	(2.10)	(1.43)	(0.64)	(0.28)	(0.26)
(in years)												
0-20	65.8	105.4	55.5	38.5	42.7	29.0	37.7	32.7	26.6	14.0	14.7	15.1
20-45	25.1	-16.4	35.0	36.0	24.4	20.9	0.7	19.2	15.4	15.0	9.0	5.4
45-65	8.6	7.3	5.4	18.8	18.5	28.2	15.7	26.2	24.9	31.0	31.4	33.2
65-85	0.5	3.7	4.1	6.7	14.4	21.9	45.9	21.9	33.1	40.0	44.9	46.3
All ages	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

patterns of diseases that occurred during the second stage of the epidemiologic transition.

As noted, the substitution of degenerative diseases for infectious diseases leads to rapid mortality declines in younger ages since it is these age groups that face the highest risk of dying from infectious diseases. During this century we may observe that with each succeeding decade the contributions to gains in TLEs from the youngest age groups are replaced by greater contributions made by older age groups. Negative values indicate that mortality actually increased during the decade for those age groups and thus had a competing and negative effect on the observed change in the TLE. This explains the rather inconsistently smaller increases in the TLEs for females in the decade of 1910 to 1920 and for males in the decade of 1960 to 1970 in light of otherwise large gains in TLEs in previous and existing decades for other population subgroups. By the turn of the twenty-first century the oldest age groups are projected to contribute significantly larger proportions to gains in life expectancy by comparison to younger age groups.

Within specific age groups the U.S. Office of the Actuary has projected quite different patterns of change. For example, for both sexes the relative contributions to gains in longevity from the youngest age group (0 to 20) are projected to level off by 1990 at approximately 15 percent of the contribution to changes in TLEs from birth to age 85. The second age interval (20 to 45) is projected to make successively smaller contributions since mortality in these ages has already declined to such low levels that further significant declines are not expected. Contributions previously made by younger age groups are projected to be replaced by contributions to gains in TLEs made by older age groups, with the largest contribution projected to be made by the population aged 65 to 85.

It should be noted, however, that the increased relative contributions to gains in TLEs by older cohorts will occur under conditions where the absolute TLE increases are projected to be much smaller than those experienced in previous decades. The timing of this decrease and the pace of improving TLEs shown here is a function of the assumption about mortality change made by the U.S. Office of the Actuary. Such a decline is expected to occur as we approach the biological limits to mortality declines, although the time period in which mortality compression will occur is still in question. Nevertheless,

this transformation in the relative importance of mortality change at opposite ends of the age structure during this century illustrates clearly another dimension of the movement into the fourth stage of the epidemiologic transition.

### *Shifts in the Age Distribution of Death*

Although the first three stages of the epidemiologic transition have been characterized by a substitution of one set of diseases for another, it is implied here that the fourth stage is characterized by a substitution of the *ages* at which degenerative diseases tend to kill. In effect, this means that while it is likely that degenerative diseases will remain with us as the major causes of death, the risk of dying from these diseases during this stage in our transition is thought to be progressively redistributed from younger to older ages.

Evidence for this redistribution process exists in the literature. For example, Manton (1984) analyzed the distribution of the age at death for the United States population from 1962 to 1979. It was determined that for all causes the mean age at death had increased by 3.2 years for males and 5.8 years for females from 1962 to 1979. Increases in the mean age at death imply that for these selected time periods the distribution of death for the population was shifting in the direction of older ages. Similar shifts had also occurred for the population aged 60 and over and for specific major degenerative causes of death. Interestingly, the standard deviations of ages at death had also increased during this time period for the population aged 60 and over. This implies that instead of a compression of mortality in advanced ages that has been hypothesized by other researchers (Fries 1980; Fries and Crapo 1981), there is some dispersion in the distribution of death occurring in conjunction with the delays. This shift in the distribution of death, however, cannot go on indefinitely in the face of a biological limit to life and it is, therefore, inevitable that mortality compression will occur eventually.

Manton (1984) has illustrated this delay process using means and standard deviations of ages at death. Another way of following this delay process is to observe changes in the percentage distribution of deaths through the age structure for all causes and specified degenerative causes of death. If a shift in the age progression of mortality is occurring, then we would expect that for successive time periods there

would be relatively fewer deaths in younger ages and increases in the percentage distribution of deaths in older ages. This is the equivalent of simply shifting the age distribution of deaths for a given year a selected number of years along the x-axis in the direction of older ages while leaving constant the relationship of the curves to one another. With a shift *and* a compression of mortality we would expect the distribution to appear more narrow and show a higher peak in older ages by comparison to previous years.

In figure 3 we see the percentage distribution of all causes of death for males and females at ages 40 and over in the United States for the decades of 1960 through 1980. According to this figure, in each succeeding decade a consistent pattern emerged where deaths that previously had occurred in younger ages were replaced by a larger proportion of deaths in advanced ages. Note how the peak ages at death occurred 10 years later and were less dispersed for females (75 to 89) than for males (65 to 79). Within sex groups from 1960 to

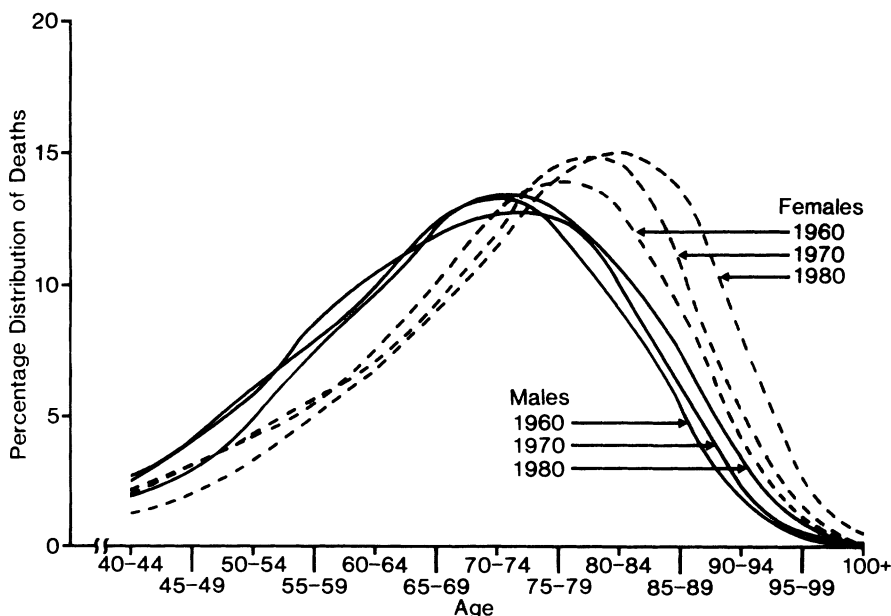


FIG. 3. Percentage distribution of deaths from all causes for the U.S. population at ages 40 and over, by sex (1960, 1970, 1980).

1980 it appears that the distribution merely shifted toward older ages with no evidence of compression.

While similar patterns emerge for the specific causes of death taken separately, there are notable exceptions. For example, while the distribution of death for ischemic heart disease (figure 4) illustrates a consistent shift in the direction of older ages for successive decades for males and females, the relative distributions of death in the three peak age groups in 1980 represented 8.3 percent more of the deaths for females (52.6) than it represented for males (44.3). As a result there was less dispersion of deaths for females. With cerebrovascular diseases the age distributions were shifted five years farther in the direction of older ages than that which was experienced for all causes for both males and females (see figure 5). In the case of malignant neoplasms (figure 6) the distribution of deaths for males and females peaked at the same ages (65 to 74), and they were relatively higher and less dispersed for males—a pattern quite different than for other degenerative causes of death.

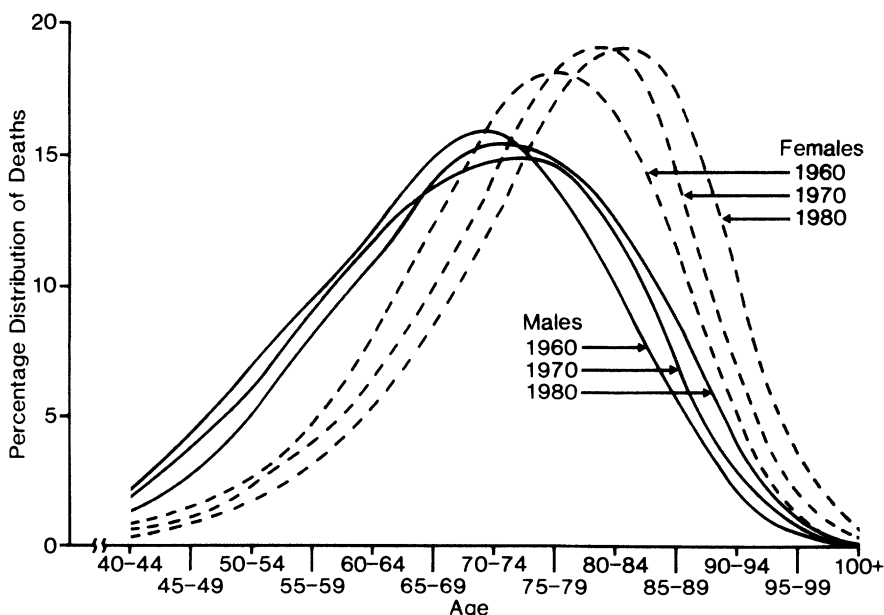


FIG. 4. Percentage distribution of deaths from ischemic heart disease for the U.S. population at ages 40 and over, by sex (1960, 1970, 1980).

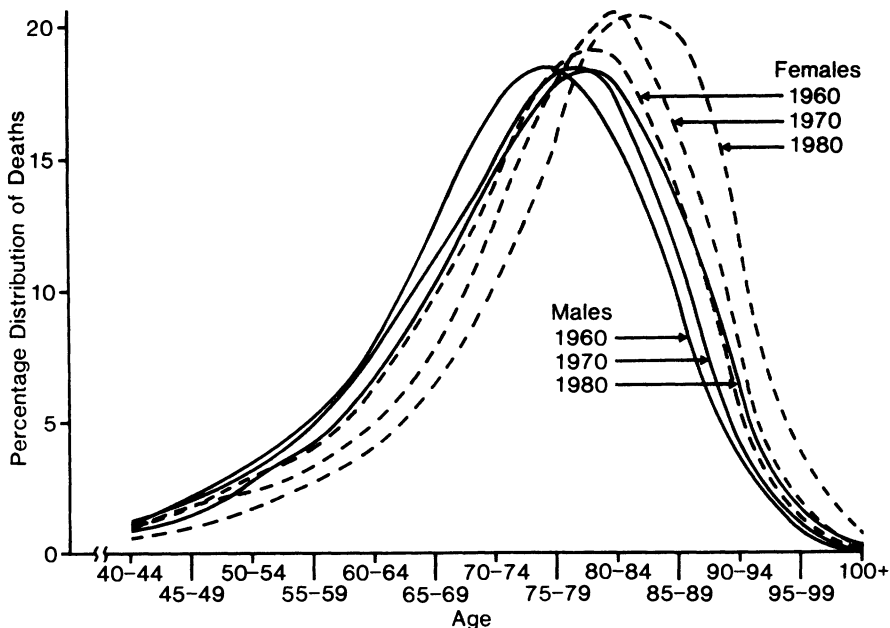


FIG. 5. Percentage distribution of deaths from cerebrovascular disease for the U.S. population at ages 40 and over, by sex (1960, 1970, 1980).

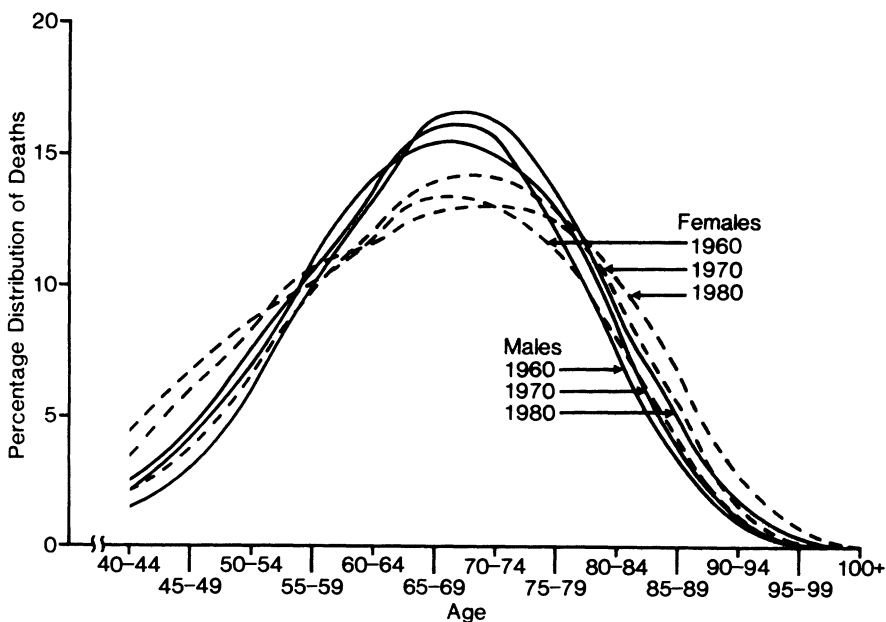


FIG. 6. Percentage distribution of deaths from malignant neoplasms for the U.S. population at ages 40 and over, by sex (1960, 1970, 1980).



These data suggest that while varying patterns exist in the age distribution of death by sex and for specific causes taken separately, generally the trend from 1960 to 1980 has been a shift in the distribution in the direction of older ages with larger shifts occurring in the latter decade. There is also no evidence from these data on selected degenerative causes to suggest that mortality was compressed into advanced ages during the time periods considered here.

## Implications

The era of delayed degenerative diseases is likely to have numerous impacts on two major demographic variables, the size and relative proportions of the population in advanced ages, and the health and vitality of the elderly.

Several studies have estimated prospective changes in the size and relative distributions of the population in advanced ages for the United States and other developed nations (Siegel 1979, 1980; Siegel and Hoover 1984; Rice and Feldman 1983). For example, Siegel (1979) has projected that by the year 2020 the population aged 65 and over in the United States will double from 23 million in 1976 to about 45 million. All segments of the elderly population are expected to grow dramatically, particularly the extreme aged (aged 85 and over). While projections of absolute numbers of the elderly are fairly reliable because they depend solely upon assumptions about mortality for a population that is already alive, alternative mortality assumptions based upon *delays* in degenerative diseases (instead of an extrapolation of past trends) indicate that there could be as many as 1.5 million more people over the age of 65 in the United States by the year 2020 than that projected by the U.S. Bureau of the Census (Olshansky 1984). In this regard it is important to recognize that even minor differences in projection assumptions about mortality can produce rather large differences in the absolute number of people expected to be alive in advanced ages in the future.

The proportions of the elderly as a function of the total population are also expected to increase by the second decade of the next century. While the major demographic component that will bring forth increases in the absolute number and proportions of people in advanced ages is different size cohorts moving through the age structure, rapid

mortality declines in advanced ages tend to accelerate the aging of the population by allowing larger proportions of successive birth cohorts to survive into advanced ages. The fourth stage of the epidemiologic transition will, therefore, accelerate the growth rate of the absolute numbers of elderly in the population, and it will place an additional upward pressure on the rate of population aging beyond that expected from the temporal shifts in the age structure. This phenomenon of population aging is a demographic process currently being experienced by developed and developing nations throughout the world (Myers 1982).

Although the numbers and proportions of the elderly are viewed as a potential problem for social service programs, this issue is now giving ground in importance to the potential impact of declining mortality in advanced ages to issues of health care (Manton and Soldo 1985; Manton 1982). The central issue here is that of "vitality"—or the question of whether declining mortality in advanced ages will result in additional years of health or additional years of senescence. At one extreme it has been suggested that future mortality declines will result in a simultaneous compression of mortality *and* morbidity into advanced ages (Fries 1980). At the other extreme it has been argued that the survivors—the population "saved" as a result of declining mortality in advanced ages—may increase both the individual and aggregate number of years spent in a state of frail health or senescence by the elderly (Gruenberg 1977; Kramer 1980; Schneider and Brody 1983). It has even been suggested that both phenomena will occur at the same time (Feldman 1983). That is, improved survival may lead to an increase in the proportions of the population with a short duration of functional impairment, and an increase in the proportion of the population with a longer duration of functional impairment (i.e., survivors to advanced ages in the future may experience the extremes of frailty depending upon what causes the mortality declines).

There are two other issues to consider when the topic of prospective trends in morbidity is discussed. The first involves basic demographic arithmetic. The prevalence of morbidity in a population is a product of the incidence rate and the size and age distribution of the population. Given that incidence rates of morbidity are known generally to increase as a function of age, then as a *population* ages there will inevitably be an accompanying increase in the prevalence of morbidity—assuming the rate of its occurrence remains constant. For example, scientists

have suggested that even with declines in morbidity rates, the absolute number of people expected to reach advanced ages in the near future will be so large that the effects of changes in age composition outweigh any likely declines in the rate of morbidity, thus resulting in increased prevalence (Kramer 1980; Gruenberg 1977). Others have argued that even with rapid increases in the absolute size of the elderly population, it is possible that the mortality declines that are expected to occur among cohorts reaching older ages in the future may be accompanied by a corresponding decline in the severity or rate of progression of chronic diseases, thus leading to a reduction in the incidence rate of morbidity (Manton 1982; Fries and Crapo 1981; Soldo and Manton 1985). In any case, if morbidity rates were to remain constant, then the fourth stage of the epidemiologic transition would inevitably exert an upward force on the *prevalence of morbidity*. The question is, is it reasonable to expect morbidity rates to remain constant in the face of rapid declines in death rates from major degenerative diseases?

A second issue involves the concepts of "competing causes" and "natural death." Competing causes is a term used to describe how diseases operate independently as risk factors in competition for the lives of individuals. Each cause of death is considered an independent increment to the force of mortality, and changes in the risk of dying from any single cause is thought not to influence the risk of dying from other causes. While the concept of competing causes has been used often as a method of estimating the effects on longevity of hypothetically eliminating causes of death, it is relevant to issues of morbidity-mortality linkages in that it illustrates how altering patterns of cause-specific mortality can influence a population's disease profile. Specifically, we know that if deaths from a given cause decline then at some point in time and at some ages the risk of dying from other causes must therefore increase. With the postponement of deaths from degenerative causes we face the prospect of substituting, for causes of death experiencing declines, other causes of death with patterns of predeath frailty that may be significantly different than those which prevail today. For example, it is possible that with rapid declines in heart disease and cancer, there may be an increased risk of frailty from more debilitating chronic conditions such as stroke or Alzheimer's disease, or from nonlethal conditions such as arthritis and blindness (Feldman 1983). This could occur during the interim of time in which deaths from degenerative diseases are postponed but not sufficiently

so as to place the survivors at an elevated risk of dying from biological constraints. Alternatively, it has been suggested that with the postponement of death from degenerative diseases the "survivors" may live into more advanced ages and face a significantly higher risk of dying a nondisease-related "natural death," with comparatively less frailty time (Fries 1980).

The term "natural death" was introduced by Fries (1980) as a concept which represents death at the biological limit to life that is caused by the incremental age-associated loss of organ reserve. Fries suggested that natural death (which was acknowledged to be a condition that few people today survive long enough to experience), is the result of the natural physiological and biologically determined process of aging that all living organisms experience, and which should be distinguished as a process separate from the age progression of chronic degenerative diseases. When the postponement of death occurs, it is suggested that the clinical manifestations of diseases are also delayed and the time available for frailty is lessened as we approach the biological limit to life (which Fries has estimated at approximately 85 years of age). However, the differences between death from biological causes and death from chronic degenerative causes are arbitrary at best. In fact, given the unrealistic assumption under competing causes that degenerative diseases operate independent of one another, it would also appear that the factors that cause "natural death" are impossibly intertwined with the factors that cause deaths from chronic degenerative diseases.

At issue here are three major assumptions that are relevant to estimates of morbidity. First, the nature and location of the biological limit to life is currently an issue for debate. Fries (1980) has estimated the average biological limit to life at about age 85, while others have estimated the biological limit at approximately 100 years of age (Cutler 1975; Havighurst and Sacher 1977). The relevance of the age of an upper bound on the lifespan to issues of morbidity is that this will determine the extent to which mortality will have to decline before a significant proportion of the population survive into the ages where they face an elevated risk of dying from single or multiple organ failure (if natural death is an appropriate description of death from biological causes).

It has also been suggested that the human lifespan may not be fixed at a single or average age at all, but instead it may actually be

increasing (Manton 1982). This conclusion was based upon evidence indicating that in the United States there have been significant mortality declines among a subgroup of the population that already has the lowest mortality—white females. Perhaps it is the case that instead of a compression of mortality and morbidity against a theoretical upper limit to life, both are merely being postponed equally into later ages—leaving constant the number of years between first permanent infirmity and death. This could change the disease profile of the population, and perhaps even the duration and nature of the frailty experienced during that interval. At this time, however, it is too early to tell whether or not the lifespan is increasing, particularly when we consider the problems of data reliability at older ages and the unique time period we appear to have entered in our epidemiologic history.

The second assumption at issue is whether or not it is appropriate to presume that the postponement of death will be accompanied by the postponement of first permanent infirmity. Previous research (Wiley and Camacho 1980) has suggested that when mortality declines are a result of preventive health care measures, morbidity may also be postponed into later ages. However, it is not certain, first, whether this phenomenon is actually occurring and whether it will continue into the future, and, second, it has yet to be determined what proportion of the mortality declines are attributable solely to preventive health care measures.

And finally, is it appropriate to assume that a biological mechanism which controls the rate of aging is separate from the age progression of chronic degenerative diseases, as Fries (1980) assumes (for more on this issue see Minaker and Rowe 1985)? Is it possible, for example, that the acquisition of healthier lifestyles on a population scale will postpone the clinical manifestations of chronic diseases *and simultaneously* slow the process of aging—thus leading to a real increase in the lifespan as has already been suggested (Manton 1982)? Or, is it possible that the repeated insults to the body that lead to the clinical manifestations of disease also accelerate the drain on organ reserve and operate to pull the biological lifespan (of individuals) toward younger ages? In this regard Hayflick (1982, 225) has suggested that “although age-associated physiologic decrements surely increase vulnerability to disease, the fundamental causes of death are not diseases but the physiological decrements that make their occurrence more likely.”

At present the scientific evidence regarding recent patterns of morbidity in the United States is far from conclusive regarding the direction in which we are headed. Recent research by Verbrugge (1984), for example, indicates that the health status of the elderly population in the United States has worsened in recent decades. Feldman (1983) has shown that disability rates due to heart disease and arthritis had actually increased monotonically from 1969 to 1980 for the population aged 50 to 69. And McKinlay et al. (1983) have demonstrated that almost all of the increase in life expectancy that occurred in the United States from 1964 to 1974 for the cohorts reaching age 45 were disability years. Yet for the cohorts reaching age 65 in those years there appear to have been slight gains in the number of years free of disability. Moreover, research by Palmore (1986) indicates that the health of the population aged 65 and over in the United States may have improved from 1961 to 1981 relative to the rest of the population. In short, there is contradictory evidence regarding the issue of recent patterns of change in morbidity in the United States, and it is acknowledged that it will continue to be difficult gauging patterns of morbidity in the future because of the inherent problems associated with its measurement.

There is one final point worth mentioning with regard to the data presented here. At present, indices of mortality change indicate clearly that we have entered a new era in our epidemiologic history in terms of survival. What is most apparent from this new transition is the force it will exert toward increasing the numbers and proportions of the elderly in the population in the coming decades. Manton and Soldo (1985) have referred to a continued emphasis on the numerical aspects of aging as solely a quantitative approach to what is really a multifaceted issue—an issue that is likely to have rather unique qualitative features. For example, because of the likelihood of a finite lifespan and the potential for changes in the disease profile of the population, this new era in our epidemiologic history may have profound influences on basic activities of daily living for the elderly, the demands for and costs of health care services and nursing home care, health care rationing, and the case mix of elderly patients in long-term and acute-care facilities, to mention a few. While these issues, as they relate to increased longevity and declining mortality, have been discussed extensively in the literature (Manton and Soldo 1985; Soldo and Manton 1985; Minaker and Rowe 1985; Cameron 1985; Rice and

Feldman 1983; McCall 1984), a few brief points are worth mentioning here.

First, on the quantitative side it has already been demonstrated (Rice and Feldman 1983) that projected changes in age composition alone (using the same mortality projection assumptions as in this study) will contribute significantly to a rapid growth in the demand for, and costs of, health care services (assuming there are no radical changes in age-specific morbidity rates). For example, 6 percent of the one-half billion increase in annual physician visits, and more than half of the 100 percent increase in the total annual short-stay hospital days that are projected to occur from 1980 to 2040, will be attributable to population aging. Furthermore, changes in age composition by the year 2040 are projected to account for a 350 percent increase in the total number of nursing home residents, a 500 percent increase in the number of nursing home residents aged 85 and over, and a 103 billion dollar increase in the health care budget for the population aged 65 and over—assuming constant 1980 dollars. Some of the largest cost increases are projected to occur for nursing home care. It should be noted, however, that the proportional contributions of projected changes in births, deaths, migration, and age composition to the growth of the elderly population have yet to be determined.

Since the fourth stage of the epidemiologic transition will serve to allow larger proportions of successive birth cohorts to survive into advanced ages, the mortality declines projected to occur during the time frame considered here certainly will exert an additional upward pressure on health care costs and demands that go beyond that expected from different-sized cohorts moving through the age structure. The nature and duration of this additional force on population aging will depend upon assumptions of how long we can expect to experience this new era in our epidemiologic history. While we know that this fourth stage must eventually come to an end given the likelihood of a finite lifespan, at present there is no indication that the pace of mortality declines in advanced ages have tapered off. In fact, the mortality projection assumptions made by the U.S. Office of the Actuary (Faber 1982) assume a 0.6 percent average annual decline in mortality rates from 1981 to 2056. This is an assumption as reasonable as any other, but it should be emphasized that even small differences in mortality projection assumptions can produce significant differences in estimates of the growth of the elderly population.

It is the potential qualitative aspects of this new era, however, that force us to consider implications for other health care issues. For example, long-term-care facilities and acute-care settings generally treat a variety of patients that require certain kinds of care and resource requirements. The consumption of resources in these facilities has been associated with the relative distribution (i.e., case-mix) of the types of patients under their care, and the beds and services in these facilities are essentially rationed, based upon assessments of how efficiently patients can perform basic activities of daily living (ADLs)—such as bathing, dressing, feeding, etc. Increased survival and possible changes in the disease profile of the elderly population leave open the prospect for radical changes in the health and vitality of cohorts reaching older ages in future decades. For instance, on the pessimistic side it is possible that increased longevity during this era could (1) prolong the period of life during which ADLs are performed less efficiently, possibly as a result of increased exposure to nonlethal debilitating conditions such as arthritis and blindness, (2) alter the disease profile of the population in favor of causes with higher predeath frailty, (3) alter the case-mix of elderly patients in acute- and long-term-care facilities in favor of more costly and more debilitating conditions, and (4) increase the demands for and costs of long-term and acute-care facilities beyond that expected from present age-specific utilization rates. On the optimistic side it is possible that we may experience (1) a postponement of the age of first permanent infirmity and a compression of the time period available for less efficient performance on ADLs into a shorter part of the lifespan, (2) a slowing of the rate of chronic disease progression and a compression of mortality into a shorter age range closer to the biological limit to life, (3) a change in the case-mix of elderly patients in favor of less frail, less debilitating, and less costly conditions, and (4) a slowdown in the rate of increase in the demands for and costs of long-term and acute-care facilities as age-specific morbidity rates decline in the face of projected increases in the numbers of elderly.

The point to be made here is not that either of these extremes in their entirety are inevitable outcomes of the fourth stage of the epidemiologic transition, but that there are some fundamental qualitative features of this stage that make these extremes possible. These qualitative features include, among others, the existence of an upper limit to life imposing possibly very different constraints on longevity, and the



potential for a change in the disease profile of the population. To quote Soldo and Manton (1985, 314), "the near inevitability of chronic morbidity and disability at advanced ages means that there will be a natural evolution of the mix of services required by an aging population . . . [and] the maturing service needs of an aged population must be taken into account to ensure the long-run fiscal viability of integrated health service systems."

## Conclusion

According to the theory of the epidemiologic transition there are three stages that have been characterized generally by a substitution of degenerative diseases for infectious diseases, and life expectancy at birth reaching approximately 70 years of age in the third stage. Based upon the analysis of mortality, life expectancy, and survival data for the United States from the turn of the century to 1980, and projections to the year 2020, the United States appears to have recently entered a fourth stage in the epidemiologic transition—a stage characterized distinctly by rapid mortality declines in advanced ages that are caused by a postponement of the ages at which degenerative diseases tend to kill. This redistribution of degenerative diseases has been referred to as "The Age of Delayed Degenerative Diseases"—a stage that will propel life expectancy into and perhaps beyond eight decades.

These conclusions are based upon mortality projections recently made by the U.S. Office of the Actuary—projections based upon an extrapolation of cause-specific mortality rates that were observed in recent years. The use of alternative mortality projection models has demonstrated that even small changes in assumptions can produce relatively large differences in projections of life expectancy (Olshansky 1985). It is therefore suggested that the data presented here should be considered cautiously with regard to projections of the pace and extent of prospective mortality declines in advanced ages. Since other research that has been based upon alternative mortality projection models and assumptions indicates that mortality declines may be greater than that projected by the U.S. Office of the Actuary (Olshansky 1984), it is possible that the pace of mortality declines may not taper

off as quickly as the data presented here indicate. At present we are unable to determine just how long this era of delayed degenerative diseases will last.

The inevitability of the growth of the elderly population, whether it is caused by larger cohorts moving into advanced ages and/or greater proportions of these cohorts surviving to advanced ages as mortality continues to decline, is certain to have a profound influence on the health care industry and social service programs for the elderly in the coming decades. Whether the influence will be positive or negative has yet to be determined. It is suggested in this paper that the age of delayed degenerative diseases represents an unexpected and perhaps welcome era in our epidemiologic history, an era that requires new ways of thinking about aging, disease, morbidity, mortality, and certainly how life will be lived in advanced ages in the very near future.

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*Address correspondence to:* S. Jay Olshansky, Ph.D., Energy and Systems Environmental Division, Argonne National Laboratory, Building 203, 9700 South Cass Avenue, Argonne, IL 60439.