The Dynamics of Population Aging: Demography and Policy Analysis

KENNETH G. MANTON

Duke University

DEMOGRAPHY, WHICH HAS LONG BEEN A RESOURCE in shaping U.S. health policy, developed from the confluence of analyses of sociostructural systems, the economics of population growth, actuarial science, and biometry. Its history dates to Graunt's (1662) work on the London life tables and bills of mortality. Subsequent innovation concentrated in the biometric and life insurance traditions, with models developed by Gompertz (1825) and Makeham (1867) still being used by biologists to analyze adult mortality and senescence (Finch 1990; Strehler 1975). Actuarial science flourished in the 1930s and 1940s, inspired, among others, by the work of Dublin and Lotka (1937), Spiegelman (1957), with extensive contributions from Scandinavian actuaries.

For decades, the *Milbank Quarterly* has published significant and important papers representing the achievements of U.S. demographers (Coale 1957; Dubos 1969; Jacobson 1964; Madigan 1957; Spiegelman 1957 [see also Kiser 1970]; Stolnitz 1957; Tarver 1959; Tomasson 1960). Omran's (1971) characterization of the "epidemiological transition," Dubos' (1969) analysis of the relationship between the environment and chronic disease in developed societies, studies on health services by Densen, Balamuth, and Seardorff (1960) and by Gruenberg (1977) are but a few of the distinguished contributions.

The Milbank Quarterly, Vol. 69, No. 2, 1991

This long tradition was carried forward during the 14-year tenure of David Willis as editor of the *Quarterly*. His own interest in demographic trends led him to welcome and encourage articles that would have great bearing on matters central to health policy. During the era of David's editorship, *Quarterly* readers encountered Fries's (1983, 1989) "compression of morbidity" thesis, which tackled the question of whether the aggregate health of the elderly was improved by increased life expectancy (e.g., Feldman 1983; McKinlay and McKinlay 1977; Rice and Feldman 1983); they also saw analyses of whether new concepts of health were required to describe chronic disease and "senescence" in an aging U.S. population (Manton 1982). Articles were published during this time that documented the potential impact of demographic changes on the need for health services. Thus, Densen (1987) extended prior analyses by combining health systems data (e.g., the New York Health Insurance Plan of 1960) with national health surveys to describe an increasingly complex U.S. health system.

A central focus of many articles in the *Quarterly*, especially during the last years of David's tenure, centered on the impact of the growth of the elderly population—the old as well as the oldest old—on the acute- and long-term care (LTC) health systems. Articles that appeared in regular *Quarterly* issues, as well as in special supplements—on the oldest old (Suzman and Riley 1985), on disability (Fox and Willis 1989), and on minority health (Willis 1987)—represented a mix of quantitative analysis and reviews of new ideas for private and public solutions to short- and long-term challenges posed by an aging population.

In this article I will review some critical aspects of the impact of the growth of the elderly population in the United States, examine the accuracy of the initial characterization of the problem, and speculate on the future course of population aging and the need for innovative health care strategies.

The Growth of the Elderly Population: A Demographic Imperative

Before the implications of U.S. population aging became nationally visible in the Social Security "crisis" of 1982 and 1983, there was little analysis of the impact of the growth of the elderly and oldest-old population on national policy. Demographers often assumed that life expectancy was "fixed" and that population growth was driven by fertility (Coale 1957; Lew and Seltzer 1970; Stolnitz 1957).

Until the late 1960s, national vital statistics showed little improvement in the mortality rates of the elderly. Through the 1950s and early 1960s, female mortality above age 65 declined modestly; in some years male mortality even increased. The National Center for Health Statistics (NCHS) stated that "the death rate for the United States has reached the point where further decreases as experienced in the past cannot be anticipated" (NCHS 1964, 42)—a view also expressed by biologists studying aging (Hayflick 1965; Strehler 1975). Dubos (1969) suggested that life expectancy past age 45 could not change. Lew and Seltzer (1970) forecast a life expectancy *eight* years *lower* than Jacobson (1964) had projected six years earlier.

Until 1975, Social Security Administration (SSA) Trust Fund projections assumed that an *absolute* limit to life expectancy would be reached in the year 2000. In the 1975 SSA projections, "ultimate" mortality rates for the year 2000 were *higher* than mortality rates observed in 1975 (Myers 1981). The Census Bureau used SSA mortality assumptions. Thus, both sets of federal projections systematically *under*-estimated growth of the 65+ population (table 1).

In 1977, U.S. Census projections underestimated the 1990 elderly population by 1.7 million persons, while projections of the 2020 elderly population were 7 million lower than is now projected. Projections based on a model of risk factor changes are presented in table 1 for comparison (Manton, Stallard, and Singer 1991). These assume that significant changes in risk factors can be achieved and suggest that the elderly population could grow even faster than in current Census projections.

The large decline in heart disease and stroke mortality in the United States, and increases in life expectancy in Japan and other developed countries, forced a reexamination of human life expectancy "limits" (see Myers and Manton 1984; Rothenberg, Lentzner, and Parker 1991). Evidence of a decline in heart disease mortality had already appeared in California in the 1950s (Borhani 1978). The causes of early declines in heart disease and stroke mortality are unclear. National hypertension control efforts did not emerge until the early 1970s (Brody 1984). By 1968 national data reflected reductions in total, cardiovascular, and stroke mortality. These changes were initially disregarded, partly because SSA and Census projections used extrapolations of long-term

TABLE 1
Selected Official Projections of the U.S. Population 65 Years of Age and Over, 1990 to 2060, and Reported Population Figures, 1950 to 1975[a]

	Date of projection (year)															
	1950	1955	1960	1965	1970	1975	1988	1989	1990	1995	2000	2005	2010	2015	2020	2060
Observed population for data	12.4	14.5	16.7	18.2	20.2	22.4	30.4[b]	31.0	31.6							
Projected										33.8[b]	34.9	36.3	39.4	45.1	52.1	70.3
"Risk factor" projections									29.4	34.9	40.3	43.7	45.4	69.9	84.6	146.3
Date of Census projections																
1977							24.9	27.3	29.8	31.4	31.8	32.4	34.8	39.5	45.1	
1975							24.5	26.1	28.9	30.3	30.6	31.1	33.2	37.6	42.8	
1972						22.2	24.1	25.9	27.8	28.8	28.8					
1971						21.9	23.7	25.5	27.5	28.6	28.8	29.1	30.9	35.1	40.3	
1970						21.5	23.5	25.5	27.6	28.7	28.8	29.1	31.0	35.2	40.2	
1967					19.6	21.2	23.1	25.0	27.0							
1964					19.6	21.2	23.1	25.0								
1962				18.2	20.0	22.0	24.5									
1958			15.8	17.6	19.5	21.9	24.5									
1955			15.8	17.4	18.9	20.7										
1953			15.7	17.3	18.9	20.7										
1950 Low		13.3	15.1													
Medium		13.5	15.5													
High		13.7	16.1													
1947 Low medium	11.3	12.9	14.7	16.3	18.1	19.9										
High medium	11.2	12.6	14.0	15.2	16.4	17.7										

Sources: Selected issues of U.S. Bureau of the Census, *Current Population Reports*, P-25 series: Population Estimates and Projections; optimal risk factor projections from Duke University, Center for Demographic Studies analysis.
[a] Figures in millions.
[b] Estimates for 1988, 1989, and 1990 from *Current Population Reports*, series P-25, no. 1018, median projection series.

mortality trends, and partly because experts believed that the "limit" to life expectancy had nearly been reached (see Bourgeois-Pichat 1978; Fries 1983; Ryder 1975).

The arguments for a "limit" stated that the quality of life in industrial societies increased chronic disease risk because of environmental pollution, dietary changes, reduced physical fitness, increased consumption of cigarettes, alcohol and drug abuse, social dissolution, and sociophyschological "stress" (e.g., Dubos 1969). Omran (1971) characterized this "third" stage of the "epidemiological transition" as the "age of degenerative and man made diseases." Economic (Graham 1957) and social (Tayback 1957) barriers to medical care access were observed for large portions of the U.S. population—a concern continuing today in debates about health insurance coverage.

As economies advanced and became more industrialized, these models suggested that life expectancy was limited by risks intrinsic to society. Chronic disease emerged as the major public health issue at the same time as infectious and childhood diseases were controlled through immunization, hygiene, nutrition, and child health programs (McKeown 1976; McKinlay and McKinlay 1977). Increasingly, it was argued that biomedical resources were disproportionately funneled into research on treatment, permitting disabled persons to live to advanced ages, while investment in disease prevention was inadequate (e.g., Gruenberg 1977).

Magnifying the effect of life expectancy increases was the high fertility between 1947 and 1963 that produced the "baby boom" cohorts. Initially, concern focused on their effect on education and the labor force (e.g., increasing the size of the primary and secondary educational systems to handle a larger volume of students). By 1982–1983 it was recognized that increased cohort size and improvements in life expectancy had major implications for Social Security and Medicare. Congressional hearings were held to examine the fiscal implications of fertility and mortality trends and to determine why the trends had not been identified earlier (Manton 1983; Myers 1981). The systematic underprojection of the elderly population led the U.S. Senate Finance Committee (1983) to conclude that the official projections had received inadequate scientific input and the uncertainty of projections had been underestimated. Both tax policy (increases in payroll taxes and employer contributions) and eligibility changes (increasing the age for Social Security eligibility from 65 to 67 beginning in 2000) were made to ensure Social Security Trust Fund solvency. Medicare entitlement age was not changed, but cost control measures, such as the Prospective Payment System (PPS), were introduced. PPS was to control Medicare hospitalization costs by establishing reimbursement through the diagnosis related groups (DRGs). These innovations have proved effective: PPS had saved $18 billion dollars for the Hospital Insurance Trust Fund by 1990. The effect on supplemental insurance (Part B services) was smaller. Trustee reports estimate that the Hospital Trust Fund will remain solvent until 2005 (Russell and Manning 1989).

Qualitative Effects of Individual Health Changes and Population Aging

As Social Security eligibility and payroll taxes were revised, concerns were expressed over two health issues. First, would increases in life expectancy result in poorer aggregate health for the elderly because the individual's longer life would be burdened with increased acute and long-term care (LTC) needs (Feldman 1983)? Would there be *more* elderly persons who, on average, would be *less* healthy and functional? Second, it was recognized that, as mortality improved at age 65 *and* at age 85, the "baby boom" cohorts who would reach age 85 between 2032 and 2048 would produce a major health policy challenge: provision of community and institutional LTC services to a significant portion of the U.S. population. Until 1982–1983, the management of elderly, chronically ill, and disabled patients mainly occurred in nursing homes. Community home health care was not well developed and little effort was directed to preventing chronic disease or disability (age-determined diseases were viewed as "natural" concomitants of aging; e.g., Brody and Schneider 1986). This was consistent with a life expectancy *"limit"*—that age-determined degenerative changes were biologically intrinsic, and that "maintenance" of the oldest old was the goal.

In the 1960s and 1970s patients were "deinstitutionalized" from state mental hospitals. These hospitals often provided chronic care for elderly cognitively impaired persons. Deinstitutionalization resulted in a rapid growth of the U.S. nursing-home population (Kramer 1980). After 1977, the growth of the nursing-home population was restricted (Densen 1987; Kramer 1980) by regulating construction of new nursing-home beds. This restriction, and the effects of PPS on hospital use, increased the clinical severity and the average age of nursing-home patients (Sager et al. 1989).

Concurrently, public health programs proved efficacious against chronic disease. In 1963–1964, the first surgeon general's report on the hazards of smoking for lung and heart disease was released; subsequent reports expanded the list of health hazards. In 1972–1973 a national program to identify and treat hypertension was started (Borhani 1978). Recently a national program to reduce cholesterol (National Cholesterol Education Expert Panel 1988) was introduced.

The national programs—and the less formal preventive efforts predating them—reduced smoking (Harris 1983), improved management of hypertension, and reduced population cholesterol levels over the period from 1960 to 1987.

Table 2 (NCHS 1989) presents favorable trends for risk factors in the elderly population. Definite hypertension declined 29 percent at ages 65 to 74. The population with high serum cholesterol declined 27 percent at ages 65 to 74. The lone exception is an increase in the proportion of elderly female smokers, although the proportion of elderly female *ex*-smokers increased.

Coupled with public programs to control risk factors was the emergence of effective treatments like bypass surgery, thrombolytic therapy, and control of coagulation disorders for myocardial infarction (Blackburn 1989). Significant progress against cancer has been made by improved early detection, although effective therapies have developed less rapidly.

Risk-factor trends translate into changes in total mortality (e.g, Multiple Risk Factor Intervention Trial Research Group 1990). Table 3 presents the proportion, and mean age, at death for heart disease, stroke, and cancer. Age at death from cancer, heart disease, and stroke increased concurrently with the risk factor changes shown in table 2. The potential gain in life expectancy for males from eliminating cancer increased from 1.9 years in 1968 to 2.8 years in 1987; for females from 2.3 to 3.0 years—even though the mean age, and proportion, of deaths caused by cancer increased.

However, the use of "independent" cause elimination life tables to estimate life expectancy limits has two problems. First, in order to eliminate the causes of death *not* resulting from senescence, they first have to be identified. Olshansky, Carnes, and Cassel (1990) selected heart disease (coded at two levels of generality), cancer, and diabetes as conditions to be eliminated. However, additional causes of death (e.g., chronic obstructive lung disease) also could be partly eliminated by

TABLE 2
Cigarette Smoking, Definite Elevated Blood Pressure, and High Risk Serum Cholesterol Levels According to Sex and Age: United States for Selected Years[a]

Sex and age	Current smoker[b]				Former smoker			
	1965	1976	1983	1987	1965	1976	1983	1987
Cigarette smoking								
Male								
20 years and over, age adjusted	52.1	41.6	35.4	31.5	20.3	29.6	31.1	31.4
65 years and over	28.5	23.0	22.0	17.2	28.1	44.4	48.1	53.4
Female								
20 years and over, age adjusted	34.2	32.5	29.9	27.0	8.2	13.9	16.4	18.0
65 years and over	9.6	12.8	13.1	13.7	4.5	11.7	18.7	19.8
	1960–62	1971–74	1976–80					
Definite elevated blood pressure[c]								
Both sexes								
Age adjusted, 25–74 years	20.9	21.7	20.1					
65–74 years	48.7	40.9	34.5					
Male								
Age adjusted, 25–74 years	20.7	22.9	23.0					
65–74 years	40.5	36.4	33.3					
Female								
Age adjusted, 25–74 years	21.0	20.4	17.4					
65–74 years	55.4	44.4	35.5					

	1960–62	1971–74	1976–80
High-risk serum cholesterol levels[d]			
Both sexes			
Age adjusted, 25–74 years	26.9	23.2	21.9
65–74 years	37.3	31.3	27.2
Male			
Age adjusted, 25–74 years	24.1	22.1	20.1
65–74 years	20.8	19.9	18.1
Female			
Age adjusted, 25–74 years	29.3	24.0	23.3
65–74 years	50.8	40.0	34.3

Source: National Center for Health Statistics. 1989. *Health, United States, 1988*. DHHS pub. no. (PHS) 89-1232, 96, 100, 101. Washington.
[a] In percent.
[b] A current smoker is a person who has smoked at least 100 cigarettes and who now smokes; includes occasional smokers.
[c] Systolic pressure ≥ 160 mm Hg or diastolic pressure ≥ 95 mm Hg, or both.
[d] Risk range: 20–29 years: >200 mg/dL; 30–39 years: >240 mg/dL; 40+ years: >260 mg/dL.

TABLE 3
Effects of Cause Elimination of Major Causes of Death on Life Expectancy at Birth and at Age 85 in the United States from 1968 to 1987

	Mean years to death									
	White males					White females				
	1968	Cause elimination effect in 1968	1987	Cause elimination effect in 1987	1968–1987 increase	1968	Cause elimination effect in 1968	1987	Cause elimination effect in 1987	1968–1987 increase
All ages										
Life expectancy (e_0)	67.9		72.4		4.6	75.4		79.2		3.8
Cancer	68.5 (14.6)[a]	1.9	71.8 (20.6)	2.8	3.3	69.3 (13.9)	2.3	72.0 (17.7)	3.0	2.7
Cardiovascular disease	71.7 (42.4)	6.4	75.8 (38.0)	5.5	4.1	79.7 (42.0)	5.5	83.3 (40.0)	5.6	3.6
Stroke	76.2 (9.6)	0.9	79.1 (5.9)	0.5	2.9	80.8 (15.2)	1.5	83.9 (9.7)	0.9	3.1
Age 85										
Life expectancy (e_{85})	4.7 (12.9)		5.4 (21.5)		0.7	5.6 (30.0)		6.9 (31.1)		1.3
Cancer	3.8 (1.0)[a]	0.3	4.5 (2.6)	0.6	0.7	4.5 (1.7)	0.3	5.4 (3.1)	0.4	0.9
Cardiovascular disease	4.7 (6.0)	3.1	5.6 (9.4)	3.4	0.9	5.7 (14.5)	3.6	7.1 (19.8)	4.8	1.5
Stroke	4.6 (2.1)	0.7	5.4 (1.9)	0.4	0.8	5.4 (5.8)	1.0	6.7 (5.1)	0.7	1.3

Source: Tabulations of national underlying cause of death files.
[a] Values in parentheses are the proportion of deaths caused by the condition after age x.

smoking cessation. Strehler (1975) assumed that only death from accidents could not be eliminated. Moreover, even though cancer and heart disease were not *eliminated*, as shown in table 3, life expectancy increased. Although heart disease may be viewed as partially eliminated (i.e., the proportion of all deaths from heart disease declined), the proportion and *age* of deaths caused by cancer increased—along with its anticipated impact on life expectancy.

The independence assumption (that elimination of a disease does not affect the risk of other diseases) is not valid at advanced ages when many persons have multiple diseases. Smoking affects many diseases—including some producing more disability than mortality. Thus, eliminating cancer by reducing smoking would necessarily reduce the risk of cardiovascular disease (CVD) and other causes of death. Changes in cholesterol and blood glucose may result from interventions (e.g., exercise), which have other effects on risk factors not yet identified (Blair et al. 1989). Cause elimination does not represent the interdependence of processes causing death at later ages.

In 1985, a *Quarterly* supplement on the oldest old characterized the current and future size of the LTC population and its health needs (e.g., Manton and Soldo 1985). Projections of the LTC population were made using the 1982 National Long Term Care Survey (NLTCS), the 1977 National Nursing Home Survey (NNHS), and SSA projections. In table 4 the 1984 NLTCS and the 1985 NNHS were used, producing substantially similar results (Manton 1989). The chronically disabled, community resident elderly population was projected to increase from 5.6 to 15.4 million between 1985 and 2060. The comparable population 85 and over is projected to increase from 1.1 to 5.6 million.

The Need for Data on Population Health Changes

Given the range of innovations in the acute and LTC systems, it is clear that nationally representative information on changes in the physical and social characteristics of the LTC and oldest-old population was needed. The 1985 supplement on the oldest old showed that detailed health and demographic data were lacking and that new data collection efforts had to be designed and fielded. Innovation was needed to deal

TABLE 4
Projections of the Community-based Disabled Elderly Population by Disability Level, and the Institutionalized Population, 1985–2060, Stratified by Age and Sex[a]

Year	Community-based disabled[b]					
	IADL limitation	1–2 ADLs limitations	3–4 ADLs limitations	5–6 ADLs limitations	Total[c]	Institutionalized[d]
Males						
Aged 65–84						
1985	611	446	226	257	1,539	221
2000	770	569	283	327	1,949	295
2020	1,180	844	435	487	2,935	427
2060	1,522	1,125	531	637	3,304	644
Aged 85+						
1985	87	106	48	63	304	112
2000	142	166	78	106	492	167
2020	213	248	116	159	736	249
2060	500	587	273	372	1,732	596
Aged 65+						
1985	698	551	274	320	1,844	332
2000	912	735	361	433	2,441	463
2020	1,381	1,092	551	647	3,670	676
2060	2,021	1,712	833	1,009	5,576	1,240
Females						
Aged 65–84						
1985	1,073	973	428	344	2,819	497
2000	1,287	1,164	513	425	3,389	598
2020	1,761	1,570	695	579	4,604	757
2060	2,204	1,975	873	743	5,793	989
Aged 85+						
1985	195	302	133	172	802	481
2000	323	502	222	286	1,333	802
2020	450	699	309	399	1,857	1,114
2060	934	1,448	642	829	3,853	2,287
Aged 65+						
1985	1,267	1,275	562	517	3,621	978
2000	1,610	1,666	735	711	4,722	1,401
2020	2,211	2,269	1,004	977	6,561	1,871
2060	3,138	3,423	1,515	1,572	9,647	3,277

Source: Manton (1989).
[a] Numbers in thousands.
[b] From the 1984 National Long Term Care Survey.
[c] Totals may reflect rounding error.
[d] From the 1985 National Nursing Home Survey.

with the special problems posed in interviewing the oldest old (Corder and Manton 1991; Manton and Suzman 1991). A two-year study on federal statistics for an aging population (National Research Council 1988) reenforced those conclusions by recommending both the overhaul of federal data systems (e.g., supplement the oldest-old component of national samples) to improve data on the oldest old and to develop methods for collecting data in that population (e.g., linking administrative records to survey data; developing new longitudinal sampling and survey technologies).

In the book version of the oldest-old supplement (Suzman, Willis, and Manton 1991), it was possible to report that a number of data innovations and improvements had occurred since 1985. Reported were preliminary analyses of the 1984 Supplement on Aging to the National Health Interview Survey and the 1986, 1988, and 1990 longitudinal follow-ups fostered by the 1985 special issue. The NLTCS was extended, first from 1982 to 1984, and then to 1989 (with a planned 1993 survey) with linkage to Medicare Part A and B expenditure records. Three follow-up next-of-kin surveys were conducted in the 1985 NNHS. In the 1987 National Medical Expenditure Survey, institutional and other survey components were designed to characterize elderly populations.

With improved longitudinal data, many innovations in the national acute and LTC health systems can be evaluated. To link reimbursement to good health outcomes, strategies were needed to target populations with special needs. This required new measures of health outcomes (e.g., active life expectancy; Katz et al. 1983). Procedures to combine multiple data sources were developed. Liu, Manton, and Liu (1990) integrated results from three federal surveys (i.e., the 1986 Longitudinal Study on Aging, the 1982–1984 NLTCS, and the 1985 NNHS) to evaluate private LTC insurance products. The new data increased the capacity to forecast the health and functioning of the disabled elderly population and to improve simulations and forecasts of policy interventions on health.

Methods of Payment for Care

The growth in the elderly population will necessitate the development of public policies that will control costs while effective services are developed and extended. It will also require the introduction of alternative models of care. Complicating the policy responses to population aging is the hyperinflation (twice the base inflation rate [U.S. Department of Health and Human Services 1988]) of medical costs. Inflation was the result not only of new technology, but also of changes in health insurance practices and increases in administrative costs (e.g., the General Accounting Office [GAO] estimated that private health insurance consumes 11 percent of costs in administration, compared with 2 percent for Medicare). Thus, new methods for fiscally managing acute and LTC services were needed.

DRG-based payment, derived from the Medicare success, was instituted by state Medicaid programs (e.g., Pennsylvania) and private insurers. Prospective payment (i.e., putting the provider at fiscal risk to increase efficiency) was extended experimentally to other services. Resource utilization groups (RUGs) were examined for use in nursing-home reimbursement and, currently, a Health Care Financing Administration (HCFA) demonstration is examining prospective reimbursement of home health care. LTC demonstrations (e.g., the Medicaid 2176 waiver program; the National Channeling Demonstration) were conducted to determine if case management and other LTC services would maintain the health and functioning of the elderly, and be "budget neutral" or "cost effective."

Although community-based LTC programs proved beneficial to both clients and informal caregivers in the LTC demonstrations, they did not prove budget neutral or cost effective. The search for cost-effective programs continues (e.g., the Social/Health Maintenance Organization [S/HMO] and PACE demonstrations). Although not globally cost effective, some programs were cost effective in subpopulations. "Channeling" assessed whether increasing case management use (with and without supplementary payment) improved client outcome. In "channeling," case managers tried to redistribute services among subgroups (e.g., elderly females with moderate impairment and high education but limited social resources) under a budget restriction. Thus, although there was little overall change, subgroups received very different levels of services under the intervention. Such "targeting," while technically difficult, needs further examination. In addition, the "control" group was not prohibited from receiving case management. "Controls" most in need of care were more likely to receive it (Manton, Vertrees, and Clark 1991). This suggests a phenomenon found in evaluating community primary prevention—innovations often diffuse rapidly to the control population. Thus, the services in LTC demonstrations that appeared efficacious may also have diffused, through the private market, to the general elderly population. This makes demonstrating effects in a "controlled" trial difficult.

Finally, evaluation criteria need to be assessed. The budget "neutrality" of community LTC programs is often determined relative to nursing-home costs. This assumes that current nursing-home service is, on average, adequate. However, there are reasons to doubt that such services are "adequate"—let alone "optimal"—in maximizing the health and functioning of elderly persons (e.g., results from geriatric evaluation units [GEUs]; Rubenstein and Josephson 1989). Nursing-home costs thus may be inappropriate to evaluate the cost effectiveness of other LTC programs.

New Health Concepts and Measures for the Oldest Old

Defining health outcomes for the oldest old is difficult because of the high prevalence of comorbidity and functional impairment. One index, the QALY (Quality Adjusted Life Year; Wright 1990) uses subjective judgment to "discount" each year of life for morbidity and disability. This is difficult for the oldest old, who have a high prevalence of cognitive impairment; one example would be that excellent physical health and functioning often coexists with cognitive impairment and depression in early Alzheimer's patients. Thus, equating dissimilar physical and cognitive traits using subjective criteria is problematic and potentially dangerous (La Puma and Lawlor 1990).

Active life expectancy (ALE; see Sullivan 1971) disaggregates life expectancy into the number of years expected to be lived with objectively measured levels and types of impairment. Each level of impairment is objectively defined (e.g., the number of activities of daily living [ADLs] impaired) and weighted by the time the individual is expected to live in that state (Sullivan 1971). ALE has been used to evaluate differences in outcomes between the S/HMO and fee for service (FFS) populations in the S/HMO demonstration (Manton et al. 1991). ALE is useful when mortality and institutional risk are not sufficiently sensitive to the intervention.

The use of ALE to assess outcomes, combined with greater detail on health characteristics of the elderly and oldest old, and measurement of health changes in longitudinal data, enables us to evaluate proposed innovations in health service and reimbursement systems. David Willis stimulated many of these changes through the *Milbank Quarterly*, setting the stage for future improvement of the LTC system and management of the oldest-old population.

The Future

It is evident that there are factors that could improve the aggregate health and functioning of the oldest-old population—thereby reducing LTC service needs on a per capita basis. Some factors are associated with past life experiences of the birth cohorts constituting future oldest-old populations. The educational level of those cohorts will increase (Myers, Manton, and Bacellar 1987). Their income and assets will improve on average (there are subgroups disadvantaged on multiple economic and health factors; see Fox and Willis 1989). Future oldest-old cohorts will have had regular medical care for most of their life, lived in environments with reduced public health hazards (e.g., childhood immunization programs; nutritional supplementation; programs against smoking and drinking), and will have had a heightened health awareness possibly leading to improved levels of physical activity and dietary control. Although this is not universally accepted (e.g., Olshansky, Carnes, and Cassel 1990), many pessimistic studies have not taken advantage of the new longitudinal data on health changes at advanced age. In addition, the future occupational and social environment of the elderly may be more "tolerant" to physical impairment, allowing future oldest-old populations to better preserve their social and economic autonomy.

Assistive Devices

In the future assistive devices will have a significant impact on the functioning of the elderly and oldest old. Changes in the use of such devices between 1982 and 1989 are shown in table 5.

The elderly population with at least one ADL impaired grew 12 percent (from 3.4 to 3.8 million)—23 percent less than the relative growth

TABLE 5

Distribution of Chronic Disability in 1982, 1984, and 1989 Among Community Residents by Assistance/Assistive Device and Number of Activities of Daily Living (ADLs) Impaired

Assistance/ assistive device	1982				1984				1989			
	1–2 ADLs	3–4 ADLs	5–6 ADLs	Total	1–2 ADLs	3–4 ADLs	5–6 ADLs	Total	1–2 ADLs	3–4 ADLs	5–6 ADLs	Total
Active personal assistance and equipment	132,476 (7.59)[a]	212,399 (28.66)	584,740 (63.92)	929,615 (27.33)	133,046 (7.71)	204,198 (26.80)	520,588 (62.30)	857,831 (25.34)	183,454 (9.40)	422,660 (40.43)	616,476 (76.76)	1,222,590 (32.17)
Active personal assistance only	359,727 (20.61)	212,696 (28.70)	225,041 (24.60)	797,463 (23.44)	264,538 (15.33)	202,521 (26.58)	214,920 (25.72)	681,979 (20.15)	263,861 (13.52)	207,932 (19.89)	125,930 (15.68)	597,723 (15.73)
Passive personal assistance and equipment	184,663 (10.58)	86,486 (11.67)	51,869 (5.67)	323,019 (9.50)	176,704 (10.24)	99,737 (13.09)	184,663 (6.49)	340,530 (10.06)	197,115 (10.10)	125,659 (12.02)	30,760 (3.83)	353,533 (9.30)
Passive personal assistance only	121,131 (6.94)	30,015 (4.05)	32,292 (3.53)	183,438 (5.39)	136,669 (7.92)	23,163 (3.04)	36,609 (4.21)	121,131 (5.96)	93,483 (4.79)	11,395 (1.09)	9,637 (1.20)	114,516 (3.01)
Equipment only	890,678 (51.03)	198,763 (26.82)	10,520 (1.15)	1,099,961 (32.34)	954,442 (55.31)	231,398 (30.37)	7,353 (0.88)	1,193,194 (36.46)	1,182,302 (60.58)	273,584 (26.17)	6,746 (0.84)	1,462,632 (38.49)
Not done	56,900 (3.26)	0,667 (0.09)	10,429 (1.14)	67,996 (2.00)	60,224 (3.49)	991 (0.13)	5,348 (0.64)	66,563 (2.03)	31,421 (1.61)	4,182 (0.40)	13,573 (1.69)	49,176 (1.29)
Total	1,745,400	741,100	914,800	3,401,492	1,725,623	761,931	835,614	3,384,962	1,951,637	1,045,412	803,122	3,800,171

Source: National Long Term Care Survey for 1982, 1984, 1989.

[a] Numbers in parentheses are percents.

(15 percent) of the total elderly population (26.9 million to 30.8 million). In the table the number of disabled elderly persons using passive or active personal assistance and special equipment (or a combination of the three) is presented. Active personal assistance is usually associated with formal or informal community LTC services. For persons with at least one ADL impaired, the use of active assistance *decreased* from about 24 percent in 1982 to almost 16 percent in 1989. The use of "equipment only" *increased* from 32 percent to 38 percent. A majority (69 percent) of disabled elderly persons used special equipment, either alone or in conjunction with other forms of assistance. This increased to 80 percent in 1989. If standby or passive assistance were provided through electronic aides (e.g., medical alert systems), the role for special equipment is 3 to 5 percent larger.

Congressional proposals to expand Medicare benefits to include LTC have focused on personal assistance for persons with a specific level of impairment. This could force substitution of personal care for assistive devices—even for persons currently coping with assistive devices—and thus provide perverse financial incentives. It might reduce the level of social autonomy among the elderly. These proposals have not utilized the detailed longitudinal information now available on services used by the LTC population: assistive devices *already* provide more LTC service than personal assistance, and are increasing in importance.

There are emerging technologies that could further help deal with chronic impairment and do not require personal assistance. The use of new materials (e.g., carbon fiber in leg prostheses) has produced vastly improved devices that allow persons with lower-leg amputation not only to walk better, but even to compete in sporting events. These prostheses both cushion the shock of hitting the ground and use the kinetic energy stored in an air bag when stepping off the ground. This simulates leg motion by transferring energy provided by the quadriceps to the point at which the missing calf muscle would operate. Electronic sensors of the position of the artificial limb on the person's body, and in relation to the ground, facilitate coordination of movement with prostheses. There are technical advances aiding persons with sensory loss (e.g., plastic implantable lenses for cataract patients). Largely unexplored is the use of "expert" or artificial intelligence systems to monitor the activities of mildly demented patients or of "voice activated" systems for profoundly physically impaired persons.

Health and Functioning Interventions

Clinical studies (e.g., Rubenstein and Josephson 1989) and national surveys (e.g., Harris and Feldman 1991; Manton 1988; Manton, Corder, and Stallard 1991) suggest that disability is reversible for a significant number of elderly persons—even at advanced ages. Rubenstein and Josephson (1989) show, in a randomized trial, that a GEU (a multidisciplinary diagnostic, evaluation, and treatment facility) was able to diagnose previously missed medical conditions, including depression, reduce functional impairment, and increase survival. Wieland (1989) reviewed a wide range of GEU studies. Many showed positive results even when GEUs were organized differently. Gains were achieved in elderly populations with significant functional impairment. In addition GEUs proved cost effective.

Recent evidence suggests that physical activity can reduce total mortality at advanced ages (see e.g., Blair et al. 1989; Lindsted, Tonstad, and Kuzma 1991; Paffenberger et al. 1986). Blair et al. (1989) showed that moderate exercise, *after* controlling for known risk factors, improved overall survival—an effect that increased with age. Lindsted et al. (1991) found that physical activity increased survival up to 95 or 100 years of age. Other studies (Fiatarone et al. 1990) showed that the functional ability of wheelchair-bound nonagenarians was improved (many were able to get out of wheelchairs) by weight training, which increased quadricep strength an average 174 percent.

The ability to improve muscle strength up to age 90 and beyond is consistent with the findings of longitudinal studies of aging (e.g., Rowe 1988). Muscle performance does not appear to degenerate even at advanced ages. Consequently much physical frailty is caused by lack of physical activity. Rowe (1988) and others show that physical activity positively affects a number of physiological parameters (e.g., glucose tolerance, cholesterol levels) in addition to muscle strength.

Given the potential for improving health and functioning at advanced ages, what might be expected for the health of future oldest-old populations? In table 6, we compare estimates of impairment and institutionalization in the 1982, 1984, and 1989 NLTCS. The elderly impaired population increased less rapidly over the seven years (10 percent) than the total elderly population (15 percent). Thus, on average, since 1982, there has been an *improvement* of health and functioning

TABLE 6
Cross-Sectional Distributions of Disability and Changes in Population Sizes for 1982, 1984, and 1989

	1982[a]	1984[b]	1989[c]
Nondisabled	20,447,200 (75.98)	21,375,961 (76.23)	23,694,356 (76.90)
IADLs[d]	1,585,410 (5.89)	1,805,410 (6.44)	1,612,804 (5.23)
1–2 ADLs[e]	1,745,400 (6.49)	1,725,623 (6.15)	1,951,637 (6.33)
3–4 ADLs	741,100 (2.75)	761,931 (2.72)	1,045,412 (3.39)
5–6 ADLs	914,800 (3.40)	835,614 (2.98)	803,122 (2.61)
Institutional population	1,477,100 (5.49)	1,535,507 (5.48)	1,704,665 (5.53)
Total disabled and institutional population	6,463,810 (24.02)	6,664,085 (23.77)	7,117,640 (23.10)
Total	26,910,910	28,040,046	30,811,996
		Change from 1982 to 1984 (%)	Change from 1984 to 1989 (%)
Percent change in disabled portion of community resident population (per year)		+3.10 (1.54/year)	+6.81 (1.32/year)
Percent change in total population over 65 (per year)		+4.20 (2.08/year)	+9.89 (1.90/year)
Relative rate of change of total population over 65 to rate of change in disabled population		+35.48	+45.23
			Changes from 1982 to 1984 (%)
Percent change in total population (per year)			14.50 (1.95/year)
Percent change in disabled population (per year)			10.12 (1.39/year)
Percent change in nondisabled population (per year)			15.88 (2.13/year)

[a] Cross-sectional estimates adjusted from Manton and Liu (1984).
[b] Estimates prepared using Census Bureau cross-sectional weights.
[c] Taken as the square root (1982–1984) or fifth root (1984–1989) of total percent change.
[d] Instrumental activities of daily living.
[e] Activities of daily living.

in the elderly. Not only did functioning improve on a per capita basis (the growth of the elderly population still causes absolute increases in the numbers disabled), but those changes further increase life expectancy because of large differences in morality among impairment levels. These differentials increased with time, that is, mortality *declined* for the nondisabled and increased for the extremely disabled from 1982 to 1989. In figure 1, changes in the distribution of disability by level are presented for 1990 and 2060. The proportions have been adjusted so that they add up to 100 percent (i.e., each is divided by the total proportion disabled) to provide greater detail on the impaired population. The projections assumed a slow decline in the rate of low-level functional impairment (see Manton, Stallard, and Woodbury 1991 for details). Even with improvement in function, a large absolute growth of the disabled elderly population is still most evident for the oldest old in the disability categories reflecting cognitive impairment and moderate physical impairment. The "highly impaired" category increases rapidly above age 85. The simulated improvements are based on GEU results showing that moderately impaired persons are most likely to improve.

Total life expectancy and life expectancy components for the nondisabled population (disability status 1) and disabled subpopulations are presented in table 7. These match life expectancy at age 85 projected by the SSA for 2005. They imply modest improvements in life expectancy for males above age 65 and significant improvement (about two years) for females. The amount of time to be lived without impairment is higher for males than females because of the greater time females can expect to be in institutions.

The model used to estimate ALE (Manton, Stallard, and Woodbury 1991) included the effect of "senescence." By stratifying on disability, 60 to 70 percent of the effect of senescence on mortality was explained. This implies that loss of function was strongly related to the unobserved risk factors, which determined the form of the dependence of mortality on age. Observed risk factors, in contrast, had effects proportional to age—controlling them reduced the level of mortality but did not change the shape of the mortality curve (Manton, Stallard, and Singer 1991). Functional impairment, by limiting physical activity, caused adverse changes in multiple physiological functions and, through that feedback, accelerated organ failure leading to death. Intervening to prevent that feedback produced large gains in life expectancy.

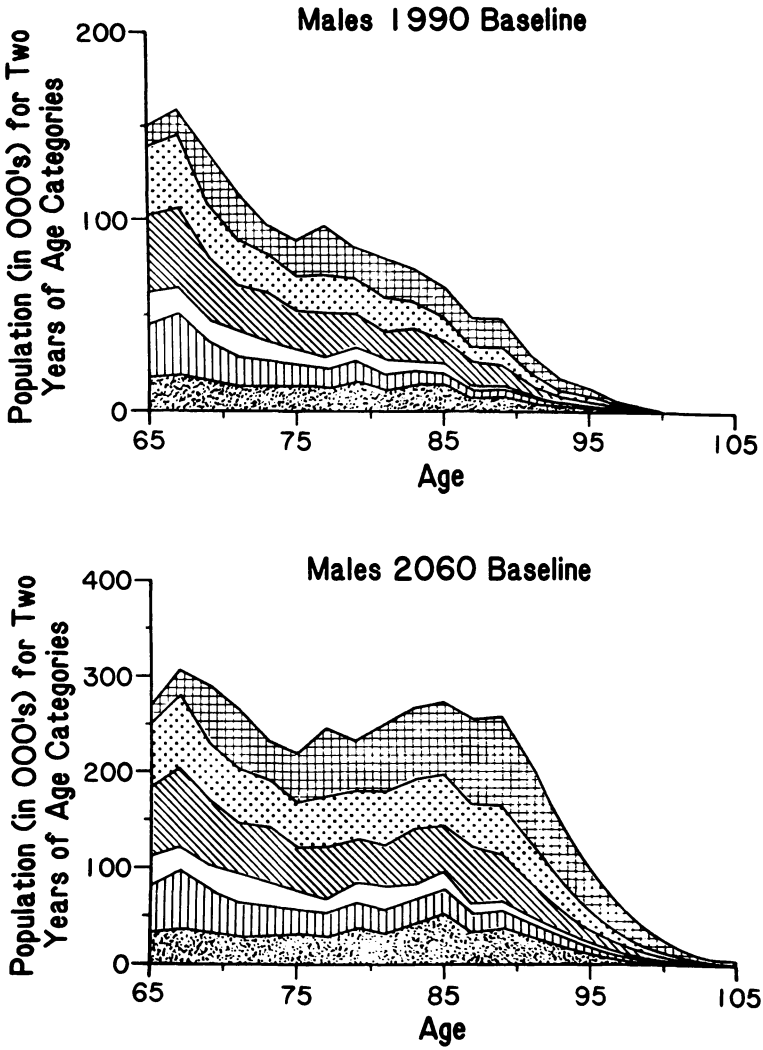
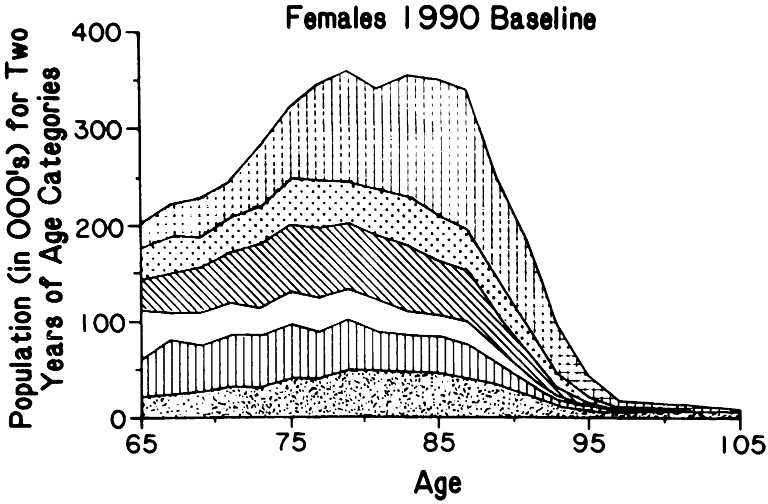


FIG. 1. Changes in the distribution of disability by levels. ▨ early cognitive impairment; ▥ moderate physical impairment; □ heavy physical impairment; ▧ frail; ⚃ highly impaired; ▦ institutionalized.

Conclusion

The tenure of David Willis as editor of the *Milbank Quarterly* produced results, and left a tradition, with far-ranging consequences. One consequence is the identification and description of aging and the



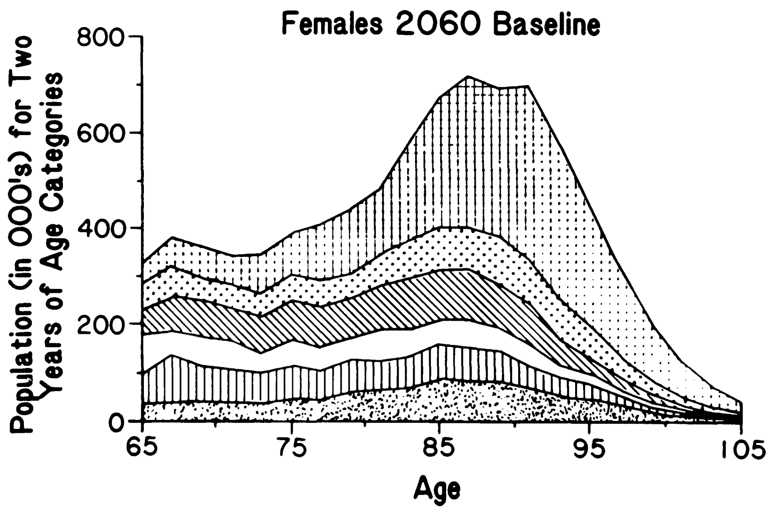


FIG. 1. *continued.*

growth of the oldest-old population. Another is the implementation of new and improved data-collection strategies. A third is use of the improved data to better design and stimulate new programs.

These results came at a critical point. The life expectancy of the elderly population has increased, magnifying the effect of the larger size of new elderly cohorts to produce unprecedented growth in the 65+ and 85+ populations. Population aging, given other problems with our

TABLE 7
Decomposition of Life Expectancy by Disability Status for Males and Females at Selected Ages

Age	Life expectancy at age *x* (in years)	Life expectancy in functional class (in years)						
		1 Healthy	2 Early cognitive impairment	3 Moderate physical impairment	4 Heavy physical impairment	5 Frail	6 Highly impaired	Institutional
Males								
65	15.41	13.42 (87.11)[a]	0.298 (1.93)	0.227 (1.47)	0.146 (0.95)	0.444 (2.88)	0.406 (2.64)	0.465 (3.02)
75	10.71	8.75 (81.75)	0.328 (3.07)	0.185 (1.72)	0.123 (1.15)	0.411 (3.84)	0.395 (3.69)	0.512 (4.78)
85	6.62	4.69 (70.86)	0.337 (5.09)	0.165 (2.49)	0.084 (1.26)	0.405 (6.11)	0.378 (5.71)	0.561 (8.48)
95	4.39	2.89 (65.91)	0.264 (6.00)	0.119 (2.71)	0.060 (1.36)	0.283 (6.44)	0.313 (7.12)	0.459 (10.46)
Females								
65	20.47	16.20 (79.15)	0.550 (2.69)	0.559 (2.73)	0.440 (2.15)	0.717 (3.50)	0.614 (3.00)	1.388 (6.78)
75	14.16	10.01 (70.66)	0.559 (3.95)	0.451 (3.19)	0.366 (2.58)	0.663 (4.68)	0.593 (4.19)	1.523 (10.76)
85	8.52	4.72 (55.42)	0.514 (6.03)	0.349 (4.10)	0.269 (3.16)	0.520 (6.10)	0.567 (6.66)	1.579 (18.53)
95	5.52	2.61 (47.33)	0.458 (8.30)	0.230 (4.16)	0.176 (3.18)	0.330 (5.97)	0.486 (8.80)	1.230 (22.27)

Source: National Long Term Care Survey for 1982 and 1984.
[a] Figures in parentheses are percentages of life expected in disability state.

health care system, could pose dire future consequences. No matter how we respond, the absolute amount of resources consumed in LTC must increase. It is possible, however, to reduce the impact by intervening in what had been viewed as "immutable"—the age rate of physical and functional decline for elderly individuals. This has implications, not only for reducing the aggregate level of LTC demand, but also for improving social autonomy at a personal level. It raises the question of whether society is doing all that is possible to maximize the potential of individuals at later ages. Although significant efforts have been made to utilize the full potential of the young when disabled, far more remains to be done for the elderly person with impairment.

References

Blackburn, H. 1989. Trends and Determinants of CHD Mortality: Changes in Risk Factors and Their Effects. *International Journal of Epidemiology* 18 (suppl.):210–15.

Blair, S.N., H.W. Kohl, R.S. Paffenbarger, D.G. Clark, K.H. Cooper, and L.W. Gibbons. 1989. Physical Fitness and All-Cause Mortality. *Journal of the American Medical Association* 262:2395–401.

Borhani, N.O. 1978. Mortality Trends in Hypertension, United States, 1950–76. In *Proceedings of the Conference on the Decline in Coronary Heart Disease Mortality*, eds. R.J. Havlik and M. Feinleib. DHEW pub. no. 79-1610. Washington.

Bourgeois-Pichat, J. 1978. Future Outlook for Mortality Declines in the World. *Population Bulletin of the United Nations*, no. 11. New York: United Nations.

Brody, J.A. 1984. Testimony before the Subcommittee on Savings, Pensions, and Investment Policy of the Committee on Finance, United States Senate, July 15, 1983. In *Federal Register*. Washington.

Brody, J.A., and E. Schneider. 1986. Diseases and Disorders of Aging: An Hypothesis. *Journal of Chronic Diseases* 39:871–6.

Coale, A.J. 1957. Age Distribution as Affected by Changes in Fertility and Mortality—A Further Note. *Milbank Memorial Fund Quarterly* 35:302–6.

Corder, L.S., and K.G. Manton. 1991. National Surveys and the Health and Functioning of the Aged: The Effects of Design and Content. *Journal of the American Statistical Association* 86:513–25.

Densen, P.M. 1987. The Elderly and the Health Care System: Another Perspective. *Milbank Quarterly* 65:614–38.

Densen, P.M., E. Balamuth, and N.R. Seardorff. 1960. Medical Care Plans as a Source of Morbidity Data: The Prevalence of Illness and Associated Volume of Service. *Milbank Memorial Fund Quarterly* 38:48–101.

Dublin, L.I., and A.J. Lotka. 1937. Uses of the Life Table in Vital Statistics. *Journal of Public Health.*

Dubos, R. 1969. The Diseases of Civilization. *Milbank Memorial Fund Quarterly* 47 (3, pt. 2):327–39.

Feldman, J.J. 1983. Work Ability of the Aged under Conditions of Improving Mortality. *Milbank Memorial Fund Quarterly/Health and Society* 61:430–44.

Fiatarone, M.A., E.C. Marks, N.D. Ryan, C.N. Meredith, L.A. Lipsitz, and W.J. Evans. 1990. High-Intensity Strength Training in Nonagenarians. *Journal of the American Medical Association* 263:3029–34.

Finch, C.E. 1990. Progress in the Biology of Aging. In *Improving the Health of Older People: A World View*, eds. R.L. Kane, J.G. Evans, and D. MacFadyen, 128–42. Oxford: World Health Organization and Oxford University Press.

Fox, D.M., and D.P. Willis. 1989. Disability Policy: Restoring Economic Independence. *Milbank Quarterly* 67 (suppl. 2: pts. 1 and 2).

Fries, J.F. 1983. The Compression of Morbidity. *Milbank Memorial Fund Quarterly/Health and Society* 61:397–419.

———. 1989. The Compression of Morbidity: Near or Far? *Milbank Quarterly* 67:208–32.

Gompertz, B. 1825. On the Nature of the Function Expressive of the Law of Human Mortality. *Philosophical Transactions, Royal Society of London* 114:513.

Graham, S. 1957. Socio-Economic Status, Illness, and the Use of Medical Services. *Milbank Memorial Fund Quarterly* 35:58–66.

Graunt, J. 1662. *Natural and Political Observations Made upon the Bills of Mortality.* (Reprinted by the Johns Hopkins University Press in 1939.)

Gruenberg, E.M. 1977. The Failures of Success. *Milbank Memorial Fund Quarterly/Health and Society* 55:3–24.

Harris, J.E. 1983. Cigarette Smoking and Successive Birth Cohorts of Men and Women in the United States during 1900–80. *Journal of the National Cancer Institute* 71:473–9.

Harris, T.B., and J.J. Feldman. 1991. Implications of Health Status in Analysis of Risk in Older Persons. *Journal of Aging and Health* 3:262–84.

Hayflick, L. 1965. The Limited *In Vitro* Lifetime of Human Diploid Cell Strains. *Experimental Cellular Research* 37:614–36.

Jacobson, P.H. 1964. Cohort Analysis for Generations Since 1840. *Milbank Memorial Fund Quarterly* 42:36–53.

Katz, S., L.G. Branch, M.H. Branson, J.A. Papsidero, J.C. Beck, and D.S. Greer. 1983. Active Life Expectancy. *New England Journal of Medicine* 309:1218–23.

Kiser, C.V. 1970. Mortimer Spiegelman's Contributions to Public Health Statistics. *Milbank Memorial Fund Quarterly* 48 (4, pt. 2):11–14.

Kramer, M. 1980. The Rising Pandemic of Mental Disorders and Associated Chronic Diseases and Disabilities. *Acta Psychiatrica Scandinavica* 62 (suppl. 285):382–97.

La Puma, J., and E.F. Lawlor. 1990. Quality Adjusted Life Years. *Journal of the American Medical Association* 263:2917–27.

Lew, E.A., and F. Seltzer. 1970. Uses of the Life Tables in Public Health. *Milbank Memorial Fund Quarterly* 48 (4, pt. 2):15–38.

Lindsted, K.D., S. Tonstad, and J.W. Kuzma. 1991. Self-Report of Physical Activity and Patterns of Mortality in Seventh-Day Adventist Men. *Journal of Clinical Epidemiology* 44:355–64.

Liu, K., K.G. Manton, and B.M. Liu. 1990. Morbidity, Disability and Long-Term Care: Implications for Insurance Financing. *Milbank Quarterly* 68:445–93.

Madigan, F.C. 1957. Are Sex Mortality Differentials Biologically Caused? *Milbank Memorial Fund Quarterly* 35:202–23.

Makeham, W.M. 1867. On the Law of Mortality and Construction of Annuity Tables. *Journal of the Institute of Actuaries* 8:301.

Manton, K.G. 1982. Changing Concepts of Morbidity and Mortality in the Elderly Population. *Milbank Memorial Fund Quarterly/Health and Society* 60:183–244.

———. 1983. Forecasting Life Expectancy. Testimony before the Subcommittee on Savings, Pensions, and Investment Policy of the Committee on Finance, U.S. Senate, July 15. Washington: Federal Register.

———. 1988. A Longitudinal Study of Functional Change and Mortality in the United States. *Journal of Gerontology* 43(5):153–61.

———. 1989. Epidemiological, Demographic, and Social Correlates of Disability Among the Elderly. *Milbank Quarterly* 67 (suppl. 1):13–58.

Manton, K.G., L.S. Corder, and E. Stallard. 1991. Health and Functional Changes in the U.S. Elderly Population 1982 to 1989: Evidence from the National Long Term Care Survey. *Gerontologist.* Submitted.

Manton, K.G., and K. Liu. 1984. The Future Growth of the Long Term Care Population: Projections Based on the 1977 National Nursing Home Survey and the 1982 Long Term Care Survey. Presented at the Third National Leadership Conference on Long Term Care Issues: The Future World of Long Term Care, Hillhaven Foundation, Washington, March 7–9.

Manton, K.G., G. Lowrimore, J.C. Vertrees, R. Newcomer, and C. Harrington. 1991. Differences in Health Outcomes over Time between S/HMO and FFS Service Delivery Systems. Duke University Center for Demographic Studies working paper no. M434A, Durham, North Carolina.

Manton, K.G., and B.J. Soldo. 1985. Dynamics of Health Changes in the Oldest Old: New Perspective and Evidence. *Milbank Memorial Fund Quarterly/Health and Society* 63:206–85.

Manton, K.G., E. Stallard, and B.H. Singer. 1991. Projecting the Future Size and Health Status of the U.S. Elderly Population. *Demography.* Submitted.

Manton, K.G., E. Stallard, and M.A. Woodbury. 1991. A Multivariate Event History Model Based upon Fuzzy States: Estimation from Longitudinal Surveys with Informative Nonresponse. *Journal of Official Statistics* (Stockholm, Sweden). Forthcoming.

Manton, K.G., and R. Suzman. 1991. Conceptual Issues in the Design and Analysis of Longitudinal Surveys of the Health and Functioning of the Oldest Old. In *The Oldest-Old*, eds. R.M. Suzman, D.P. Willis, and K.G. Manton, chap. 5. New York: Oxford University Press. Forthcoming.

Manton, K.G., J.C. Vertrees, and R.F. Clark. 1991. Channeling Revisited: A Multivariate Examination of the Effects of the National Channeling Demonstration on Specific Disability and Health Groups. *Journal of Gerontology.* Submitted.

McKeown, T. 1976. *The Role of Medicine: Dream, Mirage or Nemesis?* London: Nuffield Provincial Hospitals Trust.

McKinlay, J.B., and S.M. McKinlay. 1977. Questionable Contribution of Medical Measures to the Decline of Mortality in the United States in the Twentieth Century. *Milbank Memorial Fund Quarterly/Health and Society* 55:405–28.

Multiple Risk Factor Intervention Trial Research Group. 1990. Mortality Rates after 10.5 Years for Participants in the Multiple Risk Factor Intervention Trial. *Journal of the American Medical Association* 263:1795–801.

Myers, G.C. 1981. Future Age Projections and Society. In *Aging: A Challenge to Science and Social Policy*, vol. 2, ed. A.J. Gilmore. New York: Oxford University Press.

Myers, G.C., and K.G. Manton. 1984. Compression of Morbidity: Myth or Reality? *Gerontologist* 24:346–53.

Myers, G.C., K.G. Manton, and H. Bacellar. 1987. Sociodemographic Aspects of Future Unpaid Productive Roles. In *America's Aging:*

Productive Roles in an Older Society, 110–47. Washington: National Academy Press.

National Center for Health Statistics. 1964. The Change in Mortality Trends in the United States, series 3, no. 1. Washington.

———. 1989. Health, United States, 1988. U.S. DHEW pub. no. (PHS) 1232. Washington.

National Cholesterol Education Expert Panel. 1988. Report of the National Cholesterol Education Program: Expert Panel on Detection, Evaluation, and Treatment of High Cholesterol in Adults. *Archives of Internal Medicine* 148:36–89.

National Research Council. 1988. *The Aging Population in the Twenty-first Century: Statistics for Health Policy.* Washington: Commission on Behavioral and Social Sciences and Education.

Olshansky, S.J., B.A. Carnes, and C. Cassel. 1990. In Search of Methuselah: Estimating the Upper Limits to Human Longevity. *Science*, October 26.

Omran, A.R. 1971. The Epidemiologic Transition: A Theory of the Epidemiology of Population Change. *Milbank Memorial Fund Quarterly* 49:509–38.

Paffenbarger, R.S., R.T. Hyde, A.L. Wing, and C.C. Hsieh. 1986. Physical Activity, All-Cause Mortality, and Longevity of College Alumni. *New England Journal of Medicine* 314:605–13.

Rice, D.P., and J.J. Feldman. 1983. Living Longer in the United States: Demographic Changes and Health Needs of the Elderly. *Milbank Memorial Fund Quarterly/Health and Society* 61:362–96.

Rothenberg, R., H.R. Lentzner, and R.A. Parker. 1991. Population Aging Patterns: The Expansion of Mortality. *Journal of Gerontology.* Forthcoming.

Rowe, J.W. 1988. Aging and Geriatric Medicine. In *Cecil Textbook of Medicine*, eds. W.B. Wyngaarden and L.H. Smith. Philadelphia: Harcourt, Brace and Jovanovich.

Rubenstein, L.Z., and K.E. Josephson. 1989. Hospital Based Geriatric Assessment in the United States: The Sepulveda VA Geriatric Evaluation Unit. *Danish Medical Bulletin:* special supplement series on gerontology, no. 7:74–9.

Russell, L.B., and C.L. Manning. 1989. The Effect of Prospective Payment on Medicare Expenditures. *New England Journal of Medicine* 320:439–44.

Ryder, N.B. 1975. Notes on Stationary Populations. *Population Index* 41:3–28.

Sager, M., D.V. Easterling, D.A. Kindig, and O.W. Anderson. 1989. Changes in the Location of Death after Passage of Medicare's Prospective Payment System: A National Study. *New England Journal of Medicine* 320:433–9.

Spiegelman, M. 1957. New Frontiers in Medical Statistics. *Milbank Memorial Fund Quarterly* 35:48–57.

Stolnitz, G.J. 1957. Vital Trends and Age Distribution: An Added Note. *Milbank Memorial Fund Quarterly* 35:307–8.

Strehler, B.L. 1975. Implications of Aging Research for Society. *Proceedings of the 58th Annual Meeting of the Federation of American Societies for Experimental Biology*, 1974. 34:5–8.

Sullivan, D.F. 1971. A Single Index of Mortality and Morbidity. *HSMHA Health Reports* 86:347–54.

Suzman, R.M., and M.W. Riley. 1985. The Oldest Old. *Milbank Memorial Fund Quarterly/Health and Society* 63 (suppl.):177–451.

Suzman, R.M., D.W. Willis, and K.G. Manton. Eds. 1991. *The Oldest Old.* New York: Oxford University Press.

Tarver, J.D. 1959. Projections of Mortality in the United States to 1970. *Milbank Memorial Fund Quarterly* 37:132–43.

Tayback, M. 1957. Social Barriers to Optimal Health. *Milbank Memorial Fund Quarterly* 35:245–57.

Tomasson, R.F. 1960. Patterns in Negro-White Differential Mortality, 1930–1957. *Milbank Memorial Fund Quarterly* 38:362–86.

U.S. Department of Health and Human Services. 1988. *Health Care Financing: Program Statistics, Medicare and Medicaid Data Book, 1988.* HCFA pub. no. 03270. Baltimore, Md: Health Care Financing Administration.

U.S. Senate Finance Committee. Subcommittee on Savings, Pensions, and Investment Policy. 1983, July 15. In *Federal Register.* Washington.

Wieland, G. 1989. Geriatric Assessment: A Review and Guide to the Literature. *Danish Medical Bulletin:* special supplement series on gerontology, no. 7:7–23.

Willis, D. 1987. Currents of Health Policy: Impacts on Black Americans. *Milbank Quarterly* 65 (suppls. 1 and 2):1–531.

Wright, L. 1990. The Role of Aging in Establishing Social Priorities: An Economic Perspective. In *Improving the Health of Older People: A World View*, eds. R.L. Kane, J.G. Evans, and D. MacFadyen, 647–58. Oxford: World Health Organization and Oxford University Press.

Acknowledgments: Dr. Manton's efforts in this research were supported by NIA Grant No. 5R37AG07198, 5R37AG07025, 1R01AG07469, and ASPE HHS-100-90-0016.

Address correspondence to: Kenneth G. Manton, Ph.D., Research Professor, Center for Demographic Studies, Duke University, 2117 Campus Drive, Durham, NC 27706.