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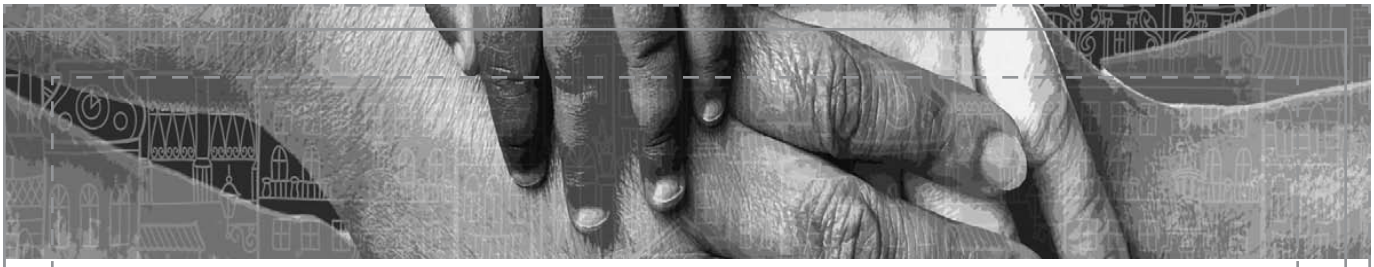

CHAPTER 1

Global Aging of the Population: The Significance of an Epidemiological Perspective

William A. Satariano and **Marlon Maus**

ABSTRACT

The purpose of this chapter is to provide an overview of **global aging** through the prism of the Epidemiologic Transition Theory. While the human population is aging, the extent and nature of that aging process vary by geographic location. There are more older adults living in the industrialized developed world, but growth in the aging population is occurring more rapidly in the developing world. Despite its overall utility, the Epidemiologic Transition Theory is a work in progress. This chapter reviews suggested ways to improve the effectiveness of the Epidemiologic Transition Theory so as to provide an evidence base for the development of programs and policies to enhance healthy aging. Finally, we consider the development of the epidemiology of aging as a field of study to foster future global studies in aging.

KEYWORDS

aged
epidemiology
healthy aging
global aging
climate change

Introduction

Today, older people constitute a larger segment of the world's population than at any other time in history. In 2010, an estimated 524 million people were **aged** 65 or older—8% of the world's population. By 2050, this number is expected to nearly triple to approximately 1.5 billion, representing 16% of the world's population (National Institute on Aging, 2011). The aging of the population is not limited to any one part of the world or segment of the population; rather, it is a global phenomenon.

TABLE 1-1 displays the current size and future projections for the size of the older population by region of the world between

TABLE 1-1 Percentage of the Total Population Accounted for by Elderly Persons, by Age and Region, 2000–2050

Region	Year	65 Years and Older (%)	75 Years and Older (%)	80 Years and Older (%)
Europe	2000	14.0	5.6	2.8
	2015	16.3	7.7	4.3
	2030	23.1	10.8	6.3
	2050	28.6	15.7	10.2
North America	2000	12.6	6.0	3.3
	2015	14.8	6.3	3.8
	2030	20.3	9.4	5.4
	2050	20.7	11.6	8.0
Oceania	2000	10.2	4.5	2.4
	2015	12.7	5.4	3.2
	2030	16.3	7.5	4.4
	2050	20.0	10.6	6.6
Asia	2000	5.9	1.9	0.8
	2015	7.7	2.7	1.3

(continues)

TABLE 1-1 Percentage of the Total Population Accounted for by Elderly Persons, by Age and Region, 2000–2050 *(continued)*

Region	Year	65 Years and Older (%)	75 Years and Older (%)	80 Years and Older (%)
	2030	11.9	4.5	2.2
	2050	18.0	8.5	4.9
Latin America/ Caribbean	2000	5.5	1.9	0.9
	2015	7.4	2.8	1.5
	2030	11.6	4.5	2.4
	2050	18.1	8.4	4.9
Near East/North Africa	2000	2.9	0.8	0.3
	2015	3.1	1.0	0.4
	2030	3.7	1.3	0.6
	2050	5.3	1.8	0.9

Reprinted with permission from NRC. PREPARING FOR AN AGING WORLD: THE CASE FOR CROSS-NATIONAL RESEARCH. In N. A. O. Sciences (Ed.), 2001 by the National Academy of Sciences, Courtesy of the National Academies Press, Washington, D.C. Data from U.S. Bureau of the Census 2000.

2000 and 2050 (Sciences National Research Council, 2001). Two points are clear from these data. First, there is considerable variation among regions. In 2000, the percentage of the population aged 65 and older ranged from 14% in Europe to 2.9% in sub-Saharan Africa. Second, as illustrated in **FIGURE 1-1**, in 2050, although Europe is expected to continue to lead the world in the percentage of older people (nearly 30%), older adults in a number of other regions—most notably, Asia, Latin America, and the Caribbean, the Near (or Middle) East, and North Africa—are expected to account for a much higher percentage of the total populations of those areas than they do today. In some cases, the percentages in the latter regions will even approximate the percentages that are expected for North America and Oceania. These data indicate that there is a difference in the percentage of people aged 65 and older between the so-called developed and developing world (or, stated differently, between high-, middle-, and low-income countries).

Between 1950 and 2050 (and even more markedly in the 2100 projection), we can see a transformation from a population pyramid to what is, in effect, a population dome

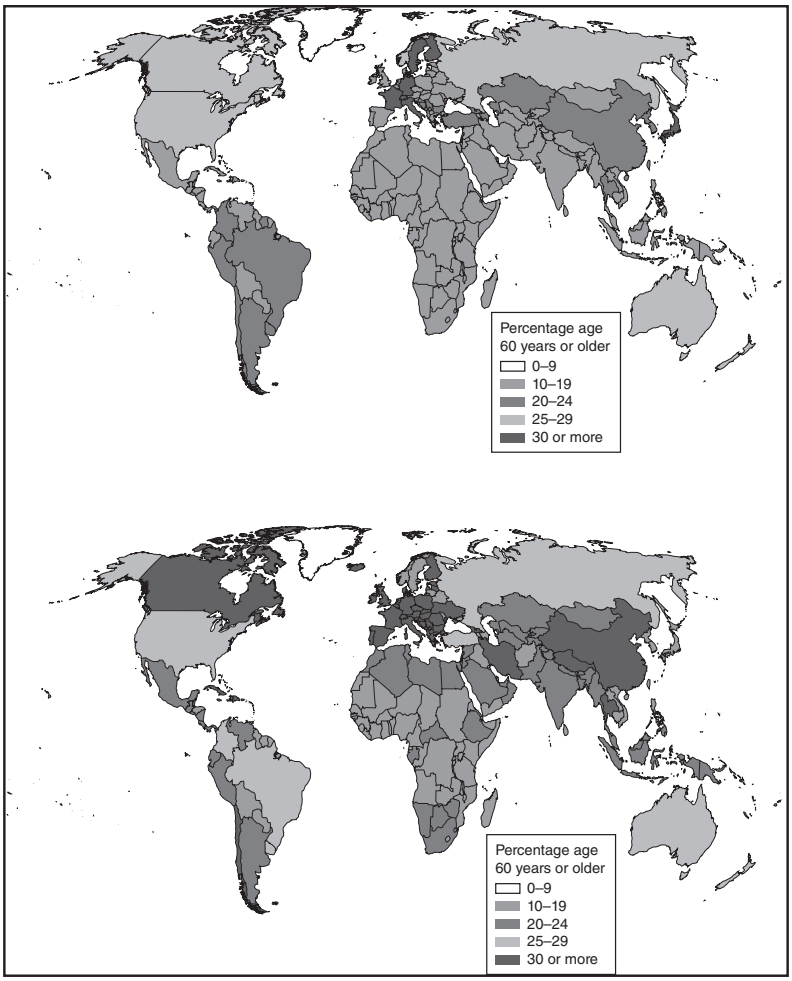

FIGURE 1-1 Proportion of population aged 60 years or older, by country, 2015–2060

Reproduced from: WHO. World report on ageing and health. 2015. Luxembourg, Luxembourg. 2015:1-260.

(**FIGURE 1-2**). In this case, the greater absolute size of the population in the developing world contributes significantly to the shape of the dome. Without the population from the developing world, the global age structure would more closely resemble an elongated tower, with very little difference in the size and distribution of the population across age groups for both males and females. Thus, it is quite clear that it is not possible to picture the aging of the population without appreciating the significance of place.

Healthy Aging and Place

Background

Why are these demographic trends so important? Put succinctly, the aging of the population represents one of the most significant public policy issues facing society today. Not only has the increase in the sheer number of older individuals focused the public's attention on

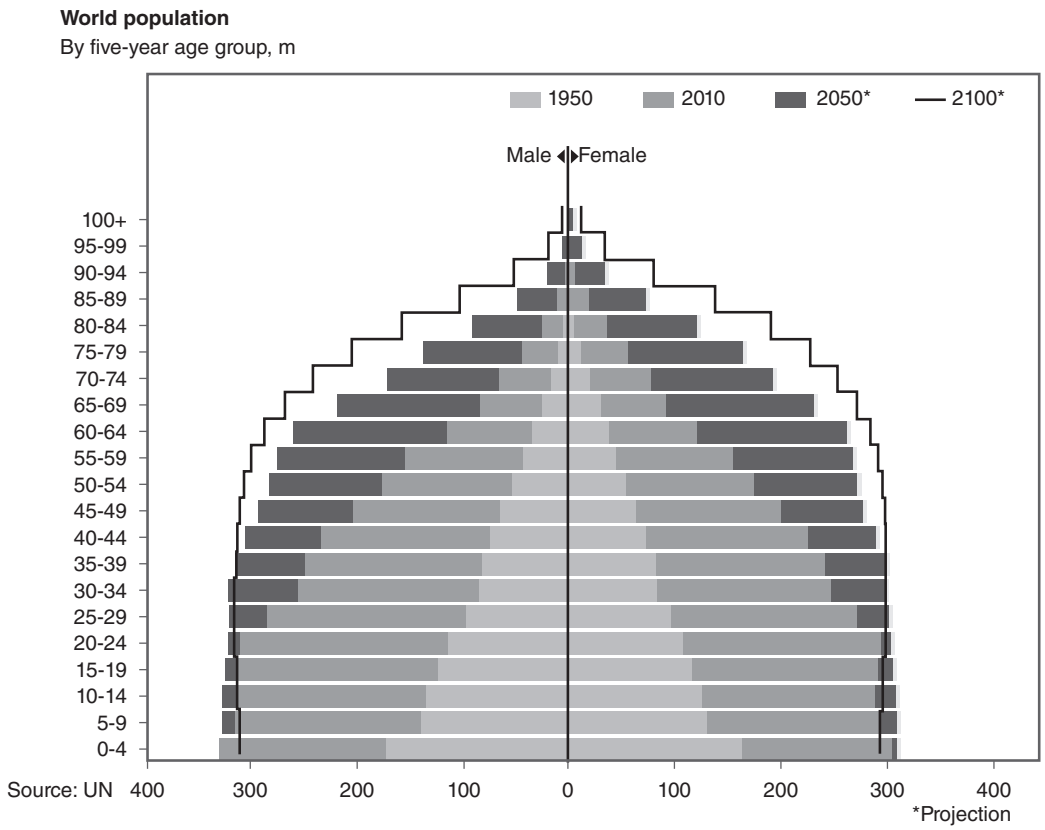

FIGURE 1-2 World population, 1950–2050 (2100 projection)

Reproduced from: UN, from "the world in 2100" 13 May, 2011. The economist online (Reprinted with permission.)

this change in demographics, but the current and future levels of that population's health and vitality are also of widespread concern. The aging of the population is associated with an increase in the incidence and prevalence of chronic diseases and disability. In addition to representing an increase in pain and suffering, it is associated with increased costs for health care and long-term services. In 2014, the World Health Assembly asked the Director-General to develop a comprehensive global strategy and action plan on aging and health. The resulting World Health Organization (WHO, 2015) strategy was designed to enhance and maintain the health and function of an aging population by focusing on the intersection of population and places. This strategy to foster "healthy aging" is also reflected in a statement prepared by the Centers for Disease Control and Prevention's (CDC) Healthy Research Network:

> Healthy aging is the development and maintenance of optimal physical, mental, and social well-being and function in older adults. It is most likely to be achieved when physical environments and communities are safe, and support the adoption and maintenance by individuals of attitudes and behaviors known to promote health and well-being; and by the effective use of health services and community programs to prevent or minimize the impact of acute and chronic disease on function (CDC, 2015).

In short, to understand and promote **healthy aging**, it is necessary to understand the significance of place.

Epidemiological Transitions and Changes in Life Expectancy

What accounts for differences in the age distribution of populations around the world? The Epidemiologic Transition Theory, as first published by Omran in 1971, was originally presented as an attempt to both describe and explain these global patterns. The basic proposition of this theory is that the increases in life expectancy (a key health outcome) have been caused primarily by changes in the age distribution of the population and associated primary causes of death—that is, by a substitution of early-onset infectious and parasitic diseases, occurring largely among infants, children, and young adult women, for late-onset degenerative causes of death, such as heart disease and cancer, occurring largely among older adults (Omran, 1971). This epidemiological transition is attributable to a variety of factors that are associated primarily with the forces of modernization. Key factors include improvements in public hygiene, sanitation, and housing; improvements in nutrition, food production, and processing; and later, immunization and other medical innovations. Likewise, improved access to formal education by females has been identified as an important factor (Aviles, 2001). Because infants and children of both genders and adolescent and young adult women are at greatest risk of early death from infectious and parasitic conditions, reduction in the incidence of these diseases led to improvements in life expectancy. The initial improvements in life expectancy, therefore, were due to early reduction of infant and maternal mortality. People, then, typically survive their early years to develop degenerative, chronic conditions later in life.

This epidemiological transition, as originally proposed, has evolved in three stages:

1. The age of pestilence and famine
2. The age of receding pandemics
3. The age of degenerative and human-made diseases

High fertility and high mortality characterized the age of pestilence and famine in primarily agrarian societies. Although mortality rates were high in this era, periodic fluctuations occurred in those rates due to epidemics that regularly affected the population. Influenza, pneumonia, diarrhea, smallpox, and tuberculosis, as well as trauma and infections associated with childbirth, were conditions that most commonly affected the population during this period.

During the time of receding pandemics, basic improvements in living standards, public sanitation, housing, and nutrition reduced the incidence of pandemics and parasitic disease, especially among infants, children, and young mothers. The development and dissemination of medical and public health measures, such as new immunization and community screening programs, sustained this transition. Following a reduction in mortality rates, a reduction in birth rates occurred. As the risk of early death from infectious and parasitic diseases declined, more people survived to their later years. A larger cohort reached the age of employability, resulting in an increase in the labor supply and an enhancement of economic productivity and associated goods and services. This outcome is described as the "first dividend" of the epidemiological transition. With the growing size of the aging population, there is an accumulation of capital and further economic development—the "second dividend" of the epidemiological transition.

When the primary cause of death is no longer infectious and parasitic diseases, but rather degenerative and so-called human-made diseases, such as heart disease, cancer, and stroke, society enters into the third period: the age of degenerative and human-made diseases. Relatively low and stable birth and death rates characterize this period. Overall, then, the transition from the first stage to the third stage results in a progressive aging of the population.

Different regions of the world are currently in different stages of development along this trajectory. Some regions of the world are presently in the third stage of development; others are not. As noted previously, the age distribution of the world population is quite variable. Indeed, Omran (1971) proposed that the nature and timing of the transition depend on the time period, country, the stage of modernization, and, it may be hypothesized, the degree of contact that a country has with other regions in different stages of transition. According to Omran, while each region may proceed through a similar demographic and epidemiological transition, each region is characterized by a different pattern, pace, determinants, and consequences of that evolution.

Omran (1971) identified three models of epidemiological transition as part of his theory. The Classic or Western Model is characterized by a gradual, progressive transition from high mortality and high fertility to low mortality and low fertility. This transition, as experienced by Western Europe and the United States, was stimulated in large part by socioeconomic factors. Specific factors included the sanitary revolution of the late 1800s, coupled with the development and dissemination of medical and public health innovations during the early period of the 1900s. In the second and third decades of the 1900s, chronic and degenerative disease replaced infectious diseases as the primary causes of death.

In contrast, the second model, the Accelerated Epidemiologic Transition Model, was evident in countries such as Japan. Although the factors that stimulated the transition in these countries were similar to the factors that affected the transition in the Classic Model, Omran (1971) contends that the process occurred more quickly. The epidemiological transition that occurred at this time and in these regions of the world was affected by interaction with other regions—the United States and Western Europe—that had made the same transition decades before. Interaction among countries may take different forms, including contact made through global systems of communication and trade.

Finally, the Contemporary (or Delayed) Epidemiologic Transition Model, the third model, characterizes the ongoing transition that is taking place today in many developing nations. Mortality rates in a number of these countries began to decline at the end of the 1800s, but accelerated after World War II. At the same time, many of these countries are still characterized by high fertility rates. Although socioeconomic factors contributed significantly to this transition, as was the case with the first two models, public health and medical interventions played, and continue to play, a more significant role in their epidemiological transition.

Some evidence has been found that supports the premise that the aging of the population in the developing countries is occurring more rapidly than it did in developed countries. One measure used by the U.S. Census Bureau is the time it takes for the percentage of people aged 65 and older in a country's population to increase from 7% to 14% of its total population. For example, in the developed world, it took more than 115 years (from 1865 to 1980) for the senior population in France to increase from 7% to 14%, compared to only 26 years (from 1970 to 1996) for this same change to occur in Japan (Kinsella & He, 2009) (**FIGURE 1-3**). In contrast, in developing countries, it is estimated that this time will range from 30 years for Chile (from 2000 to 2030) to only 15 years for Tunisia (from 2020 to 2035) (Sciences National Research Council, 2001).

Epidemiologic Transition Theory and Economic Outcomes

The epidemiological transition has important implications for economic outcomes. The population age structure is associated with issues of employment, productivity, retirement and long-term care (Mason & Lee, 2011). The epidemiological transition, as noted previously, affects the age distribution of the population

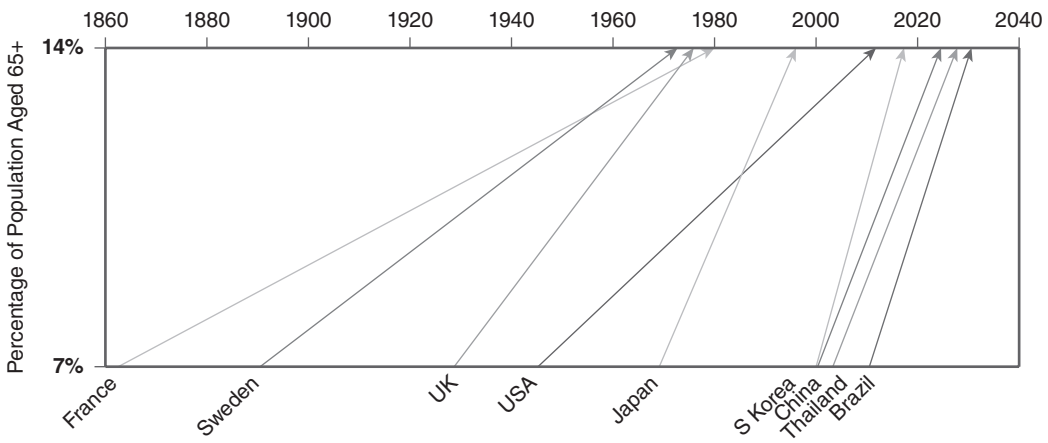

FIGURE 1-3 Time required or expected for the percentage of the population aged 65 and older to rise from 7% to 14% of the total population

Reproduced from: Kinsella K, He W. An Aging World: 2008. Washington, DC: National Institute on Aging and U.S. Census Bureau, 2009.

and, in turn, the proportion of employed and retired people in the country. As Mason and Lee (2011, p. 2) write:

> In many countries, the boom in the working-age population is drawing to a close and the future will be dominated by growth in the 60+ population. For the world as a whole, those in the working ages currently outnumber those 60+ by 4 to 1. By 2050 the ratio is projected to drop to 2 to 1. The third phase of the global age transition is without precedent. Populations in the future will be much older than ever before in human experience.

One of the major issues is to understand the effects of this epidemiological transition on the "generational economy"—that is, the intergenerational distribution and flow of economic resources. While the Epidemiologic Transition Theory outlines this process in broad strokes, one of the challenges will be to specify the economic outcomes within and between developed and developing countries over time.

One basic measure to characterize this process is the elderly support ratio. This ratio represents the number of people aged 65 and older per 100 persons aged 20 to 64. In the United States, the elderly support ratio is anticipated to increase from 21 in 2000 to 37 in 2030. While this increase is noteworthy, it is even more dramatic in other developing nations. For example, the elderly support ratio in Italy is expected to increase from 29 to 49 between 2000 and 2030; in Japan, it will increase from 27 to 52 over the same time period. Although less pronounced, the elderly support ratio is also expected to increase among developing nations. For example, in Asia the ratio is expected to increase from 12 to 26 in China between 2000 in 2030, from 9 to 15 in India, and from 11 to 27 in Thailand. In Latin America and the Caribbean, the elderly support ratio will range from 13 to 28 in Chile and from 8 to 11 in Guatemala (Kinsella & He, 2009).

In addition to summarizing the age distribution of the population, the elderly support ratio is useful for estimating the proportion of the population (those aged 20 to 64 years) theoretically available to contribute to the overall economic productivity of the country in general and to the economic support for older adults aged 65 and older in particular. (In the United States, this support comes in the form of such transfer programs as Social Security and Medicare.) The significance of the ratio

will vary with the scope of each country's economic transfer programs and the perceived need demonstrated by the country's elderly, as reflected by their level of health and functioning. Given the recent attempts to reduce trade and immigration barriers among countries, developed countries have incentives to reduce their elderly support ratios by encouraging migration of younger workers from other countries, most notably developing countries. While immigration of younger workers to countries with high support ratio is a reasonable policy, especially for the European Union, it has been a source of intense debate. Opponents of immigration cite the social and economic costs of facilitating the assimilation of immigrants. In recent years, concerns have arisen that the migrant population, especially from the Middle East, may include terrorists or people who are supportive of terrorism. No doubt that opposition to immigration contributed to the results of the 2016 referendum in the United Kingdom, in which the country's voters chose to leave the European Union ("Brexit"). Attempts to reduce costs by modifying the timing and amount of pensions have also led to intense debate and unrest, including riots in the streets of Greece and France.

The Epidemiologic Transition Theory, as originally presented, provides a parsimonious framework for considering the interrelationship of life expectancy, morbidity, and mortality within a global-historical context. It also underscores the significance of socioeconomic and environmental factors in this transition. It represents a synthesis of demographic and epidemiological principles. Despite its utility as a general framework, the theory remains incomplete—it is very much a work in progress. It is important to note that Omran (1971) concluded his original paper by acknowledging that there are inherent difficulties in attempting to formulate such a comprehensive theory, especially when it seeks to incorporate such a vast array of social, economic, demographic, and epidemiological factors. To his credit, Omran called on other researchers to assist in expanding the theory.

Epidemiologic Transition Theory: Reflections and Revisions

Age of Delayed Degenerative Diseases: A Fourth Stage

A range of issues have been raised since the publication of Omran's original paper in 1971. Fifteen years after the publication of this seminal paper, Olshansky and Ault (1986) proposed that the final stage of the theory (the age of human-made diseases) no longer accurately characterized many of the developed nations. Instead, they suggested, many of these countries were better characterized by a fourth stage—the age of delayed degenerative diseases.

When Omran's original paper was published in 1971, Olshansky and Ault (1986) argued that Omran and others did not fully appreciate the long-term significance of the decline in coronary heart disease that began in 1967 and 1968. The general consensus at the time was that life expectancy, approximately 70 years at that time, had reached its biologic limit and it was very unlikely that there would be any meaningful improvement in life expectancy beyond that point. This proved not to be the case. While the death rates declined initially among middle-aged people, later declines occurred among older age groups. The development of new drugs and antibiotics and improved methods of diagnosing and treating degenerative diseases and their complications served to postpone deaths from these diseases by slowing the rate of chronic disease progression and by reducing case-fatality rates. In addition to advances in medical technology, lifestyle changes occurred, such as reductions in smoking and improved exercise and dietary behavior. In the United States, access to health services for the elderly was improved through the introduction of the Medicare program in the 1960s. In contrast to improvements in life expectancy that were driven by reductions in infant and maternal mortality at the turn of the century,

PEARL 1-1 The Elderly Support Ratio and the Prospects of a "Third Demographic Dividend"

The elderly support ratio is a simple summary measure that indicates the number of people aged 65 and older for every 100 adults aged 20 to 64. In general, this ratio is designed to identify and monitor the older, "dependent" segment of the population as compared to the adult "productive" segment of the population. The elderly support ratio has been increasing in both the developed and developing worlds. While not a perfect measure, it suggests that an increasingly large older population may emerge that is more dependent on a shrinking productive, working population.

Linda Fried (2016), however, indicates that the future need not be so dire. She argues that if we investigate in strategies and programs to enhance the health and well-being of people across the life course, there is an increased likelihood that we will be able to produce a healthier older population—in effect, compressing multiple health and disability to the last years of life. More important, Fried contends that we can invest in programs and policies to encourage this healthier older population to continue to contribute to the well-being of society, through either paid employment or volunteerism.

Following from the Epidemiologic Transition Theory, if the first and second demographic dividends are derived from an expanding employed population and associated economic savings, then a third dividend may be obtained from the societal benefits and contributions derived from a healthy elderly population. The aging population should be thought of as a natural, renewable resource, rather than exclusively a societal challenge and problem. This means, then, that the elderly support ratio does not necessarily have to indicate "dependency," but rather "opportunity."

current and future gains in life expectancy are attributable to reductions in mortality among older age groups. Just as the initial epidemiological transitions resulted in infectious and parasitic diseases being replaced by chronic diseases, as argued by the authors, the most recent transition has resulted in the age at death changing from the young old to the oldest old.

Olshansky and Ault (1986) argued that this period of increased age at onset of degenerative conditions is important for two reasons: (1) the size, age, and gender distribution of the older population, and (2) the health and vitality of the older population. Indeed, the relationship between the increased age at onset of chronic diseases and associated levels of health and vitality continues to be a topic of some debate, especially in the United States. It is generally acknowledged today, including by Omran (1983), that the Epidemiologic Transition Theory consists of the four stages outlined in this section. Other points are being considered in more detail.

Multiple Epidemiological Transitions

Progressive and sustained improvements in life expectancy and the resultant aging of the population are fundamental propositions of the Epidemiologic Transition Theory, as originally proposed. It is assumed that all societies and regions of the world will experience improvements in life expectancy, albeit in their own time and in their own way. Although the timing of the Epidemiologic Transition Theory may vary, as represented by the three models of epidemiological transition (Classic or Western Model, Accelerated Epidemiologic Transition Model, and Contemporary (or Delayed) Epidemiologic Transition Model), it is assumed that all societies will eventually proceed through a similar process, whether it be the United States, Japan, or Tunisia. To date, however, there is only limited evidence of that common transition for a subset of developed nations.

Events in Russia and other states in the former Soviet Union after 1990 indicate that

life expectancy can be quite fragile, with any gains being lost in a relatively short period of time (Notzon et al., 1998; Shkolnikov, McKee, & Leon, 2001). Specifically, between 1990 and 1994, life expectancy for Russian men and women declined dramatically from 63.8 and 74.4 years, respectively, to 57.7 and 71.2 years. Over the same period in the United States, life expectancy increased for both men and women from 71.8 to 78.8 years, respectively, to 72.4 and 79.0 years. Closer inspection reveals that more than 75% of the decline in Russian life expectancy was due to increased mortality rates for people ages 25 to 64 years. Leading causes of death included cardiovascular diseases, injuries, pneumonia, influenza, chronic liver diseases and cirrhosis, and other alcohol-related causes. Researchers concluded that the dramatic decline in life expectancy was due to a variety of factors, including economic and social instability, high rates of tobacco and alcohol consumption, poor nutrition, depression, and deterioration of the healthcare system (Leon et al., 1997).

The presumption that the Epidemiologic Transition Model is uniform within countries has also been criticized (Gaylin & Kates, 1997; Heuveline, Guillot, & Gwatkin, 2002; Mackenbach, 1994). For example, the United States is included with other developed nations in the third or fourth stage of transition. According to some critics, this presumption neglects the heterogeneity (or health disparities) that exists with both developed and developing countries. The epidemiological profile of some residents of developed countries may actually be more akin to that posited for stage 2 than the profile associated with stage 3 or 4. This difference is reflected, in turn, in the health disparities that exist in countries such as the United States and other developed countries—disparities that are often associated with differences in race, ethnicity, and socioeconomic status. Rather than one epidemiological transition, multiple transitions may occur within single countries, with this diversity then being reflected in the heterogeneity of multiple health conditions within a country. Developed and developing countries are characterized by a variety of conditions, including both chronic and infectious diseases.

Robine and Michel (2004) argue that a general theory of population aging must take these multiple patterns into account. In a commentary that accompanied the Robine-Michel paper, Guralnik (2004) summarizes their position as follows:

> There may be a circulating back, where, first, sicker people survive into older age and disability rises, then the number of years lived with disability decreases as new cohorts of healthier people enter old age, but, finally, the number of years lived with disability rises again when the average age of death goes so high that many people spend their last years at advanced old age burdened by multiple chronic diseases and frailty. And as if all of this were not complex enough, Robine and Michel proposed that it is happening at different times in different countries and perhaps seen at different times in the same country within different population subgroups. Particularly provocative and worthy of serious consideration is their proposal that all these changes, both expansion and compression of morbidity, are part of a single unifying process, a "general theory on population aging," and are simply different stages of a single transition. (p. 606)

Primary and Multiple Causes of Death

There is also concern that the proposed transition from infectious and parasitic causes of death in stage 1 (age of pestilence and famine) to chronic disease in stage 3 (age of degenerative and human-made diseases) is overly simplistic (**FIGURE 1-4**). While a general transition

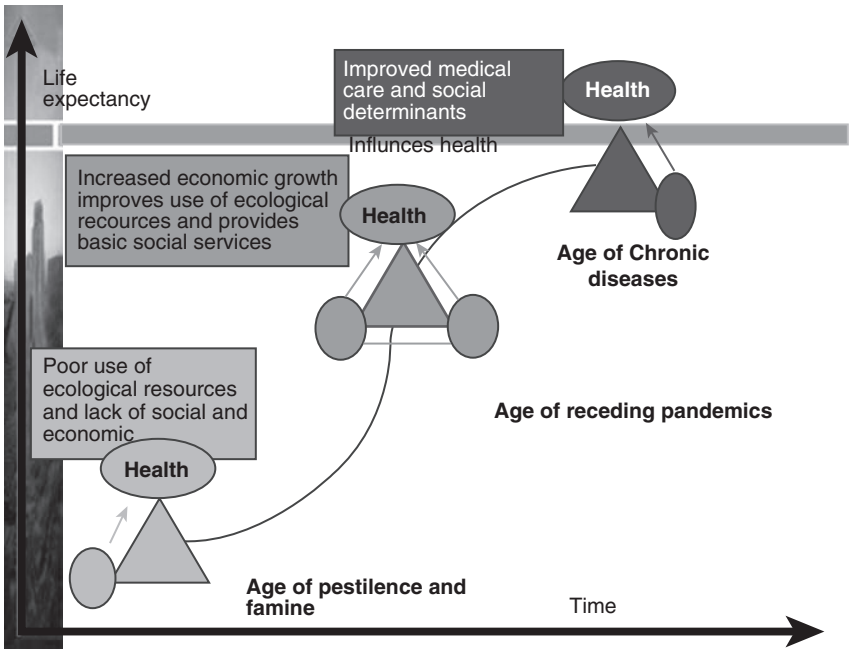

FIGURE 1-4 Epidemiologic Transition Model

Reproduced from: Manju, Pilania. Epidemiological transition. Available at: http://www.slideshare.net/ManjuPilania/epidemiological-transition-43609219, slide 10.

from infectious diseases to chronic diseases as the major health concerns might occur, the presence of other co-occurring diseases and disability is not given sufficient attention. For example, while chronic diseases may be leading causes of death during stage 3, other diseases, such as acquired immunodeficiency syndrome (AIDS) or other infectious diseases, may make significant contributions to the disease burden of a population. This is an example of syndemics, defined as "the concentration and deleterious interaction of two or more diseases or other health conditions in a population, especially as a consequence of social inequity and the unjust exercise of power" (Singer, 2009, p. xv). Syndemics may be a particular problem in developing countries. In these areas, not only do we find infectious diseases, but also the emergence of chronic conditions, such as diabetes and depression, co-occurring at the same time and among the same populations. Given the limited health and medical resources of many developing countries, their healthcare systems are not sufficiently comprehensive to deal with a range of conditions. Most importantly, the presence and severity of multiple morbidities of this kind may affect the timing and nature of the epidemiological transition and the aging of the population. It is recommended that the Epidemiologic Transition Theory be expanded to include an appreciation of health disparities within countries.

Life Changes and Epidemiological Transitions

There is a growing appreciation that aging is not confined to the last part of life, but represents a process that covers the full course of human development. Put differently, patterns of aging and the risk of disease and disability in the middle and later years are affected by events occurring earlier in life, including events prior to birth. As Kuh and colleagues (2014, p. 238) write, "A life course approach in **epidemiology** investigates the biological, behavioral, and social pathways that link physical and social exposures

and experiences during gestation, childhood, adolescence, and adult life, and across generations, to changes in health and disease risk later in life." By expanding gerontology to include elements of demography, epidemiology, and human development, it becomes possible to identify periods of vulnerability and resiliency across the life course. Moreover, one can address the temporal interaction of individual and environmental factors (both natural and built) as they influence multiple outcomes of health and well-being.

It is recommended, therefore, that a more complete consideration of the Epidemiologic Transition Theory incorporate a life course perspective—namely, information about individual and environmental factors over the life course from the early years to the middle and later years.

Climate Change

There is scientific consensus that the global climate is becoming progressively warmer, as indicated by increasing trends in both air and ocean temperatures (Intergovernmental Panel on Climate Change, 2014). **Climate change**, in turn, is associated with severe weather events, such as heatwaves, droughts, wild fires, hurricanes, and floods (HelpAge International, 2004). Other evidence indicates that climate change negatively affects agriculture and livestock, especially among subsistence farmers. Finally, climate change may elevate the risk of water- and food-borne diseases and respiratory conditions associated with a rise in increasing heat and reduction in overall air quality.

While the general population is adversely affected by conditions and events associated with climate change, the effects are especially severe among older adults (Gamble et al., 2013). Older adults are more likely than younger people to suffer from chronic conditions and disabilities, experience poorer immune function, and have less adaptive capacity. They are less likely to be mobile, whether "mobility" is defined as being able to walk for extended distances or drive a car safely during stressful and difficult circumstances (Satariano et al., 2012). They are less likely, therefore, to escape and survive major climatic events, such as floods, heatwaves, and hurricanes (Klinenberg, 2015).

It is a perfect storm. At precisely the time that we are entering a period of major climatic events and great storms, more people are reaching an age at which they are least able to deal with the environmental chaos—a stage of significant vulnerability—than at any other time in history. To date, however, these environmental data have not been included in a consideration of epidemiological transition.

Other Environmental Factors

Recent work suggests that other environmental factors may also affect the epidemiological transition. For example, Jared Diamond's book *Guns, Germs, and Steel* (1999, p. 16) is based on a question that is very similar to the basic questions that led to development of the Epidemiologic Transition Theory: "Why did human development proceed at such different rates on different continents?" Diamond contends that differences in human development and demography, such as the aging of populations, may have been affected by differences in land topography and natural resources. Specifically, differences in topography may have affected the opportunities for the production and accumulation of food through the availability and domestication of wild plant and animal species as well as the likelihood of contacts among populations and resultant opportunities for the diffusion of technology and social, political, and economic organization.

According to Diamond (1999), Eurasia had a greater variety of wild plant and animal species available for domestication. Moreover, sustained contact with animal species led to the establishment of immunities to particular types of infectious and bacterial dieses. In addition, contact and diffusion of innovations among populations were more likely in

Eurasia, because of its east-west major axis and the relative absence of such geographic barriers as major north-south mountain ranges. In contrast, interhemispheric diffusion made no contribution to Native America's complex societies, which were isolated from Eurasia at low latitudes by broad oceans, and at high latitudes by geographic barriers and a climate suitable only for hunting and gathering. Together, these factors helped to support the development of a larger, more diverse, and more organized population in Eurasia. Work similar to Diamond's can serve as a model to broaden the scope of the Epidemiologic Transition Theory.

Epidemiologic Transition Theory: Final Thoughts

The Epidemiologic Transition Theory has contributed to our understanding of the global patterns of aging and longevity among developed and developing nations. The strengths of this theory can be summarized as follows:

- The theory casts the study of aging, health, and longevity into a broad historical and global context. The causes and consequences of aging and longevity are not restricted to one country, in one period of history.
- The theory emphasizes the effects of social, economic, and political forces on changes in patterns of longevity and the age profile of nations.

Together, these characteristics set the stage for the development of global and regional strategies to understand and enhance the health and functioning of older populations.

While the Epidemiologic Transition Theory provides a broad and useful template, combining principles of demography and epidemiology, it is very much a work in progress (Omran, 1971). As noted here, it is necessary to expand the set of individual and environmental factors to better capture the global heterogeneity among and within nations. The causes and consequences of aging and health disparities should be a centerpiece of the epidemiological transition. Environmental factors must be expanded to include both the built and natural environments, as is the case with climate change. It is necessary to look beyond single causes of death to better capture the rich tapestry of health and well-being that exists in populations as part of everyday life. Moreover, the life course approach—a growing focus of researchers' attention—should be central to work in this area. Expanding our understanding in this way will require innovative strategies to obtain rich sources of data from countries throughout the world. Epidemiology will play a key role in enriching scientific research in the epidemiological transition.

Toward an Epidemiology of Aging

From a historical perspective, chronological age has been a key variable in epidemiological studies of disease and disability. Indeed, age is so closely aligned with the incidence of disease and disability that it has been necessary to adjust or "hold constant" the effects of age, so that the significance of other variables could be noted. It is ironic, then, that while chronological age has figured so prominently in the study of epidemiology, the epidemiology of aging, as a separate field, is of relatively recent origin.

In 1972, the National Institutes of Health (NIH) convened the first conference on the epidemiology of aging in Washington, D.C. The epidemiology of aging was presented (in many ways, introduced) at this conference as a field that should address the underlying physiological factors that characterized aging—in fact, the factors that served as markers of aging. These markers were considered to be distinct from individual chronic conditions, but perhaps represented the physiological foundation that affected relative host susceptibility to all

health conditions and disabilities. As Adrian Ostfeld, chairperson of the NIH conference, indicated in his opening remarks:

> The epidemiologic method has been traditionally used in the study of specific diseases, first the communicable and later the chronic disorders. Some of us think that the time has come to apply these fruitful methods to a phenomenon broader and more complex than any illness, the condition of aging itself. (*Epidemiology of Aging*, 1975, p. 1)

Ostfeld went on to describe the challenges faced by researchers in this new field:

> But the challenge of applying epidemiologic methods to the study of aging is far more difficult one than applying them to a disease. A clear, valid, and reliable definition of aging remains to be formulated. The units of aging capable of study range from intracellular enzyme activity to overall mortality rates, with subcellular particles, cells, hormones, immune processes, tissues, organs, and neural and endocrine biofeedback mechanism[s] in between. This conference represents a small beginning in considering how we may use epidemiologic methods in partnership with other disciplines in attempting to improve our understanding of aging at all levels of living organism. (*Epidemiology of Aging*, 1975, p. 1)

In 1977, a second conference was convened, in part to take stock of the progress that had been made in the intervening five years (Haynes & Feinleib, 1980). The consensus was that some progress had been made, but more governmental support was required to support the methods and sources of longitudinal data that were necessary to develop this field.

In 1974, the National Institute on Aging (NIA) was established, as part of the Research on Aging Act, as one of the institutes of the NIH. One branch of this new institute was dedicated to epidemiology, demography, and biometry. Among the primary objectives of this branch was the description and explanation of patterns of aging, health, and functioning in human populations.

The establishment of the NIA helped, of course, to draw additional attention to the emerging field of the epidemiology of aging. The epidemiology, demography, and biometry branch stimulated the development of new national population surveys on aging, such as the National Health and Nutrition Examination Survey I. This survey, together with other collaborative studies, provided a picture of the aging population. The NIA also fostered the development of epidemiological studies of aging from established population-based studies as the original cohorts of those studies aged. Exemplars for this type of study include the Framingham Heart Study, the Honolulu Heart Study, and the Alameda County Study. This was exactly the type of study called for by Ostfeld and others at the first NIH meeting on the epidemiology of aging—aging studies that reflected an efficient and effective use of current resources. The advantage of this type of study is that information has been collected for extended periods of time, often following the cohort from the middle to senior years.

More recent NIA-funded studies have used longitudinal designs that were developed specifically for the purpose of conducting research on aging. Reflecting the global significance of aging, a variety of studies of this kind have been undertaken. The NIA initiated a collaborative study in 1984 that serves as an exemplar for many of these studies. The Established Populations for Epidemiologic Studies of the Elderly (EPESE) was the first collaborative, community-based study devoted specifically to the study of the epidemiology of aging, health, and functioning (Huntley et al., 1993). It was based on three population-based

samples: East Boston, Massachusetts; New Haven, Connecticut; and selected counties in Iowa. Later, the collaboration was expanded to include selected counties in North Carolina. EPESE is important for a variety of reasons:

- Although not representative of the nation, the collaboration was perhaps the largest and most representative study of aging undertaken in the United States. The samples from New Haven and North Carolina also included valuable information about African Americans.
- The study protocol consisted of a home interview that included the respondents' reports of health and functioning as well as direct assessments of physical performance. Respondents were asked to perform specific tasks that were designed to assess upper- and lower-body function, walking speed, balance, and fine dexterity. The inclusion of these items was a major innovation in population-based studies and supported an observation made by Robert Wallace that many of the research methods used in community studies were first developed in laboratory and clinical settings.
- The EPESE protocol arguably has become the standard protocol for epidemiological studies of this kind, providing the bases for comparisons of aging populations throughout the world. For example, the protocol or key components of the protocol have been used as part of longitudinal studies in Amsterdam, Berlin, and Beijing.

Global Studies in the Epidemiology of Aging

An increased number of studies have addressed the epidemiology of aging worldwide—most notably, longitudinal studies that provide an opportunity to examine health, functioning, and longevity in aging populations. The World Health Organization has contributed significantly to the development of these global studies on aging. WHO-sponsored studies have provided useful, comparative information, which will be critical for the refinement of the Epidemiologic Transition Theory. One major contribution to the global epidemiology of aging includes the use of global measures, such as the global burden of disease (GBD). GBD was developed originally in a 1990 study by the WHO to assess the burden of disease consistently across diseases, risk factors, and geographic regions (Lopez A &, Murray, 1996).

Global Burden of Disease

Assessment of the global burden of disease entails a systematic, scientific effort to quantify the comparative magnitude of health loss due to diseases, injuries, and risk factors by age, sex, and geography for specific points in time. It measures burden of disease using the disability-adjusted life-year (DALY). This time-based measure combines the years of life lost due to premature mortality and the years of life lost due to time lived in states of less than full health. By looking specifically at health loss, rather than income or productivity loss, the GBD approach provides an opportunity to see the big picture; to compare diseases, injuries, and risk factors; and to understand in a given place, time, and age-sex group what are the most important contributors to health loss (Murray et al., 2012).

In its latest iteration, GBD 2010 has dramatically expanded the scope of the 1990 GBD exercise originally commissioned by the World Bank, which assessed 107 diseases and injuries, together with 10 risk factors. The GBD 2010 assessed 235 causes of death and 67 risk factors (Horton, 2012).

By providing a "level playing field," the GBD approach encourages a better understanding of the priorities for comparisons across countries independent of other considerations such as political or economic status. In addition, it highlights the importance of disability caused by conditions such as mental health disorders, substance use,

musculoskeletal disease, diabetes, chronic respiratory disease, anemia, and loss of vision and hearing. Particularly in an aging population, disability from disease and injury becomes an increasingly important issue for all health systems. Although current and future aging populations may be healthier than their counterparts in previous generations, more people will be spending more years of their lives with more illnesses. Women are hit especially hard by disability: Women aged 15 to 65 years lose more healthy life to disability than men (WHO, 2000).

The latest GBD measures show that 52.8 million deaths occurred in 2010 compared to 46.5 million deaths in 1990. Population health continues to improve, with life expectancies for men and women increasing, which in turn results in a greater proportion of deaths taking place among people older than 70 years. There has also been substantial progress in preventing premature deaths from heart disease and cancer in several areas around the world.

Some other measures remain subjects of concern. One in four deaths in 2010 was from heart disease or stroke, and 1.3 million deaths were due to diabetes. Deaths from road traffic injuries increased by almost half. Blood pressure is the biggest global risk factor for disease, followed by tobacco, alcohol, and poor diet. Moreover, young adults are emerging as a new and neglected priority in global health: GBD 2010 found that young adults, especially men, are dying in far higher numbers than previously (Horton, 2012).

The findings from the GBD 2010 study will improve our understanding of the priority of health challenges, as will new multicounty studies on disease epidemiology. This study should provide the essential health intelligence to help guide policy debates about the most urgent global health challenges, and how well we are addressing them (Murray et al., 2012).

The World Health Organization and other international organizations have called for more global studies on aging and more training programs in aging research (WHO, 2000, 2015). One of the concerns expressed about global studies on aging is the lack of a comprehensive and uniform evidence base. Detailed research is available for some countries, typically upper-income or developed nations, but very little has been done for developing countries. Notably, research is lacking that would support the development of a uniform evidence base for the hypotheses generated from the Epidemiologic Transition Theory. To bridge this gap, a growing set of global studies are addressing aging, including Healthy Ageing across the Life Course (HALCyon) (Kuh et al., 2014). Other studies include the Study on Global AGEing and Adult Health (SAGE), the Survey of Health, Ageing, and Retirement in Europe (SHARE), 10/66 Dementia Research

PEARL 1-2 Global Studies on Aging and Team Science

The development of a new generation of global studies on aging will require good ideas and good organization. The World Health Organization, among other national and international scientific bodies, has contributed significantly to the development of global studies in aging. These studies are critical for establishing evidence-based programs and policies to foster the health and well-being of a growing and increasingly diverse aging population. Daniel Stokols and colleagues (2008) have argued that scientific enterprises, especially those involving multidisciplinary collaboration, require effective systems of organization. Ideas do not advance in a vacuum. As we move forward to study and enhance the health and well-being of populations across the life course, we need to study, in turn, the most effective organizational strategies to achieve that end. What is the best way to bring together and sustain scientists, practitioners, policy makers, and other stakeholders to advance the study of healthy aging? Following the path suggested by Stokols and colleagues, we need to invest in the "science of team science" as it pertains to global aging.

Group, and the International Mobility in Aging Study (IMIAS). With a well-developed set of global studies, including those from developing countries, it will be possible to establish a better understanding of the epidemiology of aging. This evidence base, in turn, will serve as the foundation for practices and policies to foster healthy aging.

Epidemiology of Aging: The Core Questions

Epidemiology, both as a perspective and as a set of analytic methods, is especially well suited to examine patterns of health and functioning in an aging population. Epidemiology is based on the premise that health outcomes are not distributed randomly in the population; rather, the incidence and prevalence of health outcomes, as well as the duration and quality of life, follow specific patterns. The purpose of epidemiology is to describe and explain those patterns in the population. This information, in turn, establishes the foundation for future public health interventions. The important questions are how best to prevent and postpone disease and disability and to maintain and even enhance the health, independence, and mobility of an aging population:

- What is the overall distribution of the health outcome in the population, such as the number and types of subclinical conditions, diseases, levels of functioning, limitations, disability, and survival? How does the health outcome vary among age groups? How does it change as people age? To what extent does the health outcome vary within age groups?
- To what extent do differences among and within age groups vary by gender, race, ethnicity, socioeconomic status, and geographic region? One example is the difference among groups in the age of the onset of a particular condition.
- To what extent do differences among and within age groups vary by other factors associated with health, functioning, behavior, social factors, and the physical environment? Although these factors are important in their own right, they also serve to explain the associations between health outcomes and age, gender, race, ethnicity, socioeconomic status, and geographic region.
- To what extent are differences among and within age groups associated with age differences in the following:
  - The prevalence of the same risk factors
  - The salience or strength of the same risk factors
  - The frequency and timing of exposure over the life course to the same risk factors
  - Exposure to a different set of risk factors
- How does the timing of these factors across the life course, coupled with developmental physiological factors, affect the subsequent risk of disease, disability, and death in the middle and senior years?
- What are the biologic, behavioral, social, and environmental factors associated with the maintenance of health and functioning among older people, or so-called healthy aging? Special attention should be given to those older people who maintain their health and functioning despite having a risk-factor profile that should elevate their risk for disease, disability, and death. The study of aging and resiliency is central to a consideration of healthy aging.

Conclusion and Future Directions

The aging of the population is a global issue. This issue encompasses not just the sheer number of older people in the population, but also the implications of that aging population for patterns of health, functioning, and longevity, as well as the number and types of resources that will be needed to address the needs of that aging

population. The Epidemiologic Transition Theory is one common framework that may be used to describe and explain the patterns of health and functioning in the population. While this theory is a work in progress, it can serve as a roadmap that will pay additional dividends for our society today and in the future.

The Epidemiologic Transition Theory highlights the dividends derived from an aging population, including the expansion of the increased workforce and later an accumulation of economic assets. Linda Fried (2016) argues that we should look to the future and the potential of deriving a third dividend from the aging population. That is, as we focus on strategies to maintain health and well-being in the aging population (i.e., healthy aging), we may be able to develop strategies that will create the opportunities for older adults to contribute to the overall quality of life of the society at large. To accomplish that task and realize this third dividend, we will need to develop a global evidence base to understand more clearly why some older people are at elevated risk of health problems and functional disabilities, while others are able to maintain their health and well-being and adapt to the demands of a changing society. That information, in turn, will serve as the foundation for the practices and policies to enable a growing and increasingly diverse population to age healthfully and potentially contribute to the well-being of the society at large (third dividend). Finally, as noted by many of the authors in this volume, individual- and place-based programs and policies to enhance health and well-being must focus on people across the life course from gestation to old age.

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