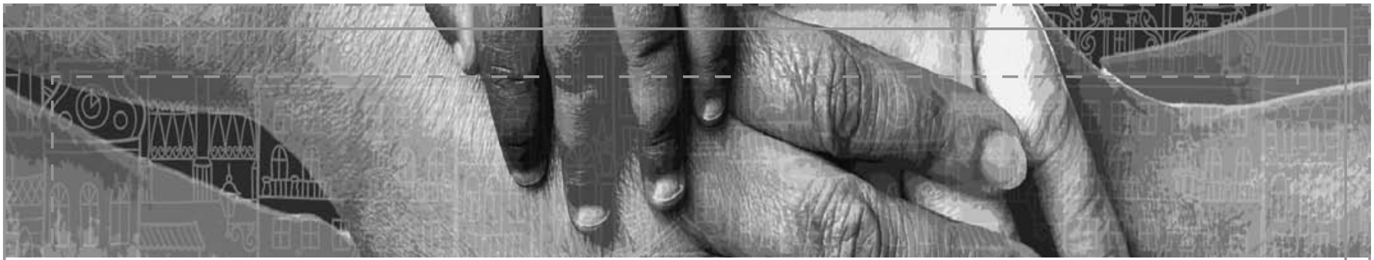

CHAPTER 2

Aging, Health, and the Environment: An Ecological Model

Marlon Maus and **William A. Satariano**

ABSTRACT

Research into the epidemiology of aging is an increasingly complex discipline in the face of a growing older population and the exponential growth of information in the field. To study, measure, describe, and test the multiple factors and hypotheses that make up the study of aging in the 21st century requires a conceptual framework that takes into account these numerous components. The ecological model is exceptionally well suited to consider the various determinants of health at multiple levels. In the framework used in this text, the model is essentially integrated into a life course perspective, as it is now generally accepted that factors occurring early in life have an important effect on how people age. The concept of "place," which suggests that where people age, including the built environment, is an essential contextual element that must also be incorporated when exploring the field of aging.

KEYWORDS

ecological model
life course perspective
epidemiology of aging
resilience
aging research

Introduction: Why Use an Ecological Model and a Life Course Perspective in the Epidemiology of Aging?

Epidemiology has been defined as the study and analysis of the patterns, causes, and effects of health and disease conditions in defined populations. It is one of the main pillars of public health, as it helps design the studies and interventions that support evidence-based practices and that shape the policy decisions that are ultimately responsible for how contemporary health care is typically provided. When epidemiology targets the fast-growing aging population, it must address various topics that are related to health, functioning, and longevity. Some of the leading areas of research include the effects of age and aging on survival and mortality and the causes of death; physical functioning, disability, and activities of everyday life; cognitive functioning; depression and other psychosocial disorders; falls and injuries; frailty and geriatric syndromes; and, of course, disease and comorbidities.

Ample evidence shows that no single factor can explain why some people—and, indeed, some populations—are able to do well as they age, whereas others do not (Violence Prevention Alliance, 2016). Rather, it is the interactions among the many factors, at many levels and over the life course, that determine the health outcomes we are considering.

The Institute of Medicine (IOM) has defined the **ecological model** as "a model of health that emphasizes the linkages and relationships among multiple factors (or determinants) affecting health" (Gebbie, Rosenstock, & Hernandez, 2003, p. 1). In the first edition of this text, the ecological model was used as a conceptual framework that focuses on the age-associated patterns of health, functioning, and longevity by considering the determinants of health at various levels from the individual and the interpersonal to the community and policy levels over the life course. The original IOM model is adapted here to illustrate the determinants and ecological nature of health across the life course and includes elements such as biological factors, personal relationships, community contexts, and wider societal factors, as well as traditional demographics such as place, gender, race, ethnicity, and socioeconomic status (Committee on Assuring the Health of the Public in the 21st Century, 2002). In addition, we incorporate more recent work that has been done to enhance our understanding of "life course" and "place"—two key components of the ecological model. We advocate that an ecological framework with a **life course perspective** is the ideal lens that can treat the interaction between factors at different levels with equal importance to the factors within a single level (Violence Prevention Alliance, 2016).

Many appeals have been made to move modern epidemiology from the study of proximate, individual-level risks to the social–ecological perspective that would allow greater insights into the complex social and environmental systems that are the context for health and disease; thinking about population health; and using life course models of disease risk acquisition (McMichael, 1999). This approach is particularly important in view of how the growing world population and economic activity are affecting the environment and its relationship with the health of an aging population.

The ecological approach is contextual in nature and requires an awareness of the multifaceted nature of the conditions and motivations for the expression of behavior across environmental conditions (Kelly, 2006). The ecological approach both to research and practice has been described as having four constituent facets: (1) It takes into account the interrelationships of persons and settings,

(2) It is based on ecological knowledge, (3) It uses a collaborative style, and (4) It is based on social processes (Kelly, 2006).

The ecological model provides a sense of "the big picture" by enabling epidemiological research in aging to combine knowledge from a wide range of scientific disciplines, including the biologic, behavioral, social, and environmental health sciences. Whereas the ecological model focuses on a static picture of an individual or a population, the addition of a life course perspective provides a temporal progression that connects the various elements of an ecological model to the health outcomes at the various stages of life. As an example, studies show that in utero exposure to the 1918 flu pandemic had long-lasting negative health consequences much later in life, including a higher probability of developing coronary heart disease, diabetes, kidney disorders, or generally poor health (Garthwaite, 2008). Other evidence shows that a cohort with fetal exposure to a pandemic performs significantly worse in terms of educational attainment and has a lower chance of marriage than its contemporaries without such exposure (Neelsen & Stratmann, 2012). This concept is explored in greater detail in the chapter on early-life predictors of late-life health.

It is not just the events very early in life that manifest themselves as changes in health late in life. In fact, events occurring at every stage in life affect subsequent stages of life. The cumulative progression that occurs over the life course can include both events with negative effects and events with positive effects. In addition, these events can, and do, take place at every level of the ecological model throughout the life course. Community and societal events, such as an economic recession or a war, may have as powerful effects on health outcomes later in life as those occurring at the individual biological level.

Finally, for a universal and comprehensive understanding of the **epidemiology of aging**, the "global perspective" approach mentioned in this text's title becomes indispensable. The study and research of health in the 21st century must take place in a vastly more interconnected world. In such a world of networks, mathematical models show that even though most nodes are not neighbors of one another, most nodes can be reached from every other node by a small number of hops or steps (Telesford, Joyce, Hayasaka, Burdette, & Laurienti, 2011). These nodes, representing individuals, their peer groups, families, communities, schools, and workplaces, are embedded in the broad economic, cultural, social, and physical environmental conditions at the local, national, and global levels, and are now intimately interconnected by technology, such as social media or ubiquitous transportation. Moreover, all of these interactions are taking place in the context of potentially cataclysmic events that know no geographic borders, such as climate change and massive population migrations resulting from political, economic, and environmental events.

The Ecological Model

In this section, we present an ecological model with a life course perspective that serves as the framework for the other chapters in this text, and is intended to be used as a guide for what is being done and an agenda for what should be done in the field of the epidemiology of aging. By looking at key topic areas in this field as outcomes rather than as distinct areas of research, we suggest that the following areas are intimately interrelated: survival and mortality; physical functioning and activities of everyday life; crashes; cognitive functioning; depression; falls and injuries; and disease and comorbidities. In addition, we attempt to integrate the conclusions from these discussions into a blueprint for future directions that may help researchers, students, and practitioners plan for potential activities and allocate resources.

An Overview

As the fraction of older adults in the world population continues to increase, the need to fulfill the World Health Organization's (WHO, 1946) definition of health—"a state of complete physical, mental, and social well-being and not merely the absence of disease or infirmity"—takes on a new level of urgency. The medical model that has dominated the U.S. healthcare system since the 19th century and for much of the 20th century is an untenable approach to preventing disease, improving health, and maintaining a state of well-being in older adults. No longer is it sufficient to look at only disease and injury and their outcomes; instead, it is necessary to recognize the importance of the social and physical environments that shape patterns of health and of disease as well as our responses to them over the entire life cycle (Fielding, Teutsch, & Breslow, 2010). Some of the determinants of health in the ecological model are listed in **TABLE 2-1**. For communities to be healthy, meaning that they have the capacity to allow each individual to be healthy, they must address all of these factors.

The idea of a social ecological perspective has its origins in the writings of Kurt Lewin, starting in the 1930s. Lewin (1935) sought to understand how individuals and their social environments mutually affect each other across the lifespan. While originating in the field of social psychology, the ecological perspective has actually been used in various disciplines for more than a century (Green,

TABLE 2-1 Examples of Determinants of Health Within an Ecological Model

Biological Factors	Living and Working Conditions
Genetic characteristics Lipid levels	Employment/living wage Income Educational attainment Healthy homes Walkable communities Transportation systems
Individual Behaviors	**Broad Social, Economic, Cultural, Health, and Environmental Conditions and Policies at the Global, National, State, and Local Levels**
Physical activity Diet Tobacco use	Climate change Medical care system Air pollution Discrimination and stigma War, terrorism, natural disaster Agricultural policy
Social, Family, and Community Networks	
Social support/social capital Intact families Schools	

Reproduced from: Fielding JE, Steven Teutsch MD M, Breslow L. A framework for public health in the United States. Public Health Reviews. 2010; 32:174., Table 1.

Richard, & Potvin, 1996). Barker (1968; writing in the field of "ecological psychology"), Bronfenbrenner, and others began to extend the ecological perspective to account for the complexity of individuals developing within embedded systems. Bronfenbrenner (1979), in particular, specified micro-, meso-, exo-, and macro-subsystems as constituting the settings and life space within which an individual develops. These levels correspond to the concentric circle levels depicted in **FIGURE 2-1**. In this model, each of the subsystems influences the individual and the other subsystems and helps us understand behavior in the context of the interplay between the individual and the environment. McLeroy further defined these concentric circles as a comprehensive social ecological model for health promotion that depicts interrelated systems at the intrapersonal, interpersonal, organizational, community, and policy levels (McLeroy, Bibeau, Steckler, & Glanz, 1988).

In the 1980s, the approach led to the development of variations of the ecological model that have been widely used in health promotion, health psychology, epidemiology, and maternal and child health. Today, these variations continue to expand and replace limited behavioral change models as means to investigate the relationship between global environmental change and human health (Stokols, 1992). For example, there is currently a considerable enthusiasm for using an ecological approach in public health and epidemiology. The ecological model has become an integral component of public health training and competencies, such as those developed by the Association of Schools and Programs of Public Health (ASPPH) and by the Council on Linkages Between Academia

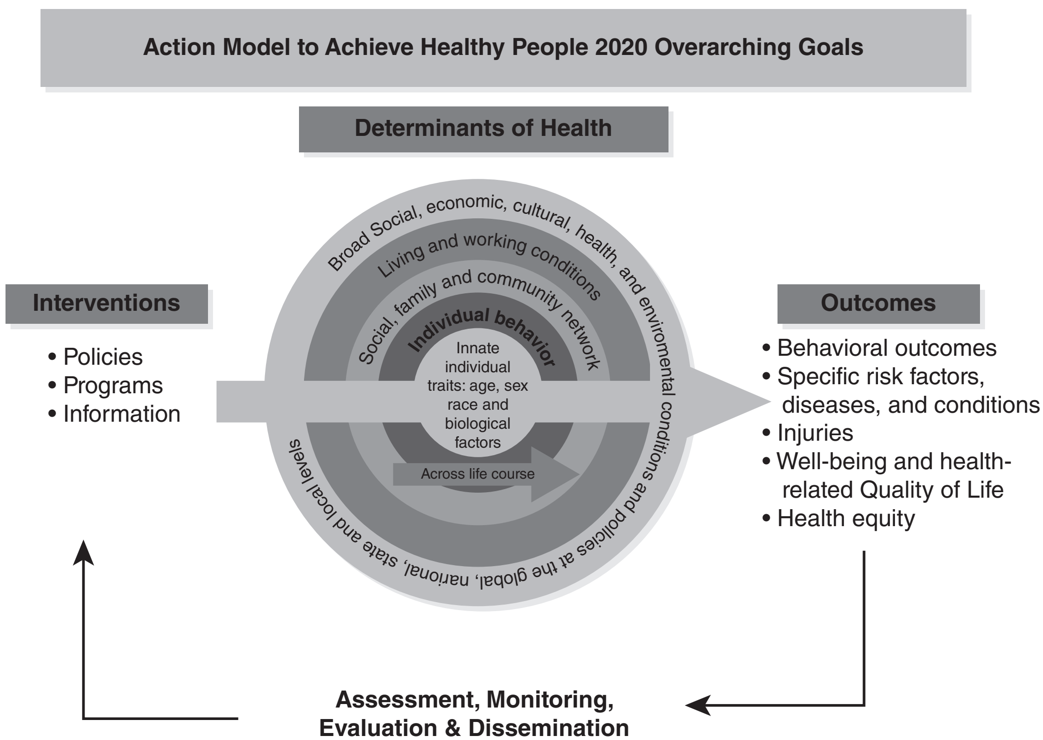

FIGURE 2-1 Action model to achieve the *Healthy People 2020* overarching goals

Reproduced from: CDC. Healthy People 2020. Secretary's advisory committee on health promotion and disease prevention objectives for 2020. In: Services USDoHaH, editor. Washington, DC: U.S. Government Printing Office; 2010.

and Public Health Practice (Public Health Foundation [PHF]).

The ecological model also serves as the basis for various position documents by leading national and international organizations, including *Healthy People 2010*, which outlines the U.S. public health agenda for the first part of the 21st century (U.S. Department of Health and Human Services, 2000); the IOM (2001) reports on health behaviors; and the model proposed for the National Institutes of Health (NIH) population disparities centers (Warnecke et al., 2008). Its usefulness and applicability to various populations and settings make the ecological framework ideal for use in the international public health arena, such as WHO's (2004) Global Strategy on Diet and Physical Activity and Health, WHO's (2003b) Framework Convention on Tobacco Control, the Bangkok Charter on Health Promotion in a Globalized World (2006), and the Ottawa Charter on Health Promotion (WHO, 1996).

Finally, the ecological model is able to take into account various determinants of health in a broader context, making it especially relevant in view of the need to address social inequalities in health such as socioeconomic, cultural, racial, and ethnic factors, as well as the built environment and access to health care (Krieger, 2001; Marmot, Friel, Bell, Houweling, & Taylor, 2008; Marmot & Wilkinson, 2005; Wilkinson & Marmot, 2003).

What Is It?

An ecological model is predicated on the idea that health and health behaviors are determined by influences at multiple levels, including personal (i.e., biological, psychological), behavioral, organizational/institutional, environmental (i.e., social and physical), and policy levels. It assumes that the dynamic interrelationships among these health determinants throughout the life course result in patterns of health and well-being for individuals, families, and communities (Smedley & Syme, 2001).

This model is useful to the researcher, for whom it provides a framework for the study of the epidemiology of aging. For the practitioner, use of the ecological models makes it more likely that interventions will be more effective by addressing determinants at all levels.

A practical example of the application of the ecological model is in tobacco control, where multilevel interventions, including environmental and policy components, have been effective in creating long-term, population-wide improvements in health behavior and health outcomes (*Healthy People 2020*, 2010). The ecological model suggests that the need for supportive social and physical environments, together with motivation and instruction, is necessary to produce widespread and long-lasting change.

In this text, topics are considered as health outcomes of an aging population. For each topic, we must keep in mind the ecological model where the determinants of health act at multiple levels, and recognize that the determinants and ecological nature of health act across the life course. This model also serves to connect possible interventions in public health with their health outcomes by identifying multiple points of possible intervention—from the microbiologic to the environmental levels—to postpone the risks of disease, disability, and death, and to enhance the chances for health, mobility, and longevity.

Historically, the visual metaphor for the ecological model is based on Bronfenbrenner's theory of development and seeks to capture the multilevel, integrated quality of this model (McLaren & Hawe, 2005). This depiction consists of a series of concentric circles, each of which represents a level of influence on behavior exerted by the overall physical environment, which in turn contains societies and populations (the epidemiological terrain), public policy, community, organizations, interpersonal processes, single individuals, intrapersonal factors, and individual physiological systems, tissues, and cells, and finally (in biology) molecules. There is an explicit assumption of interactions and reciprocal influences among the various levels.

In the original version of the model, there was no overt consideration of the effect of a life course perspective. Indeed, it was not until relatively recently that the importance of devoting explicit attention to human development across the life course became evident, as researchers realized that exposures in early life can be linked to outcomes in later life (*Healthy People 2020*, 2010). The perinatal and adult periods can be connected by studying how early-life factors, together with later-life factors, contribute to health outcomes (Lynch & Davey Smith, 2005). The implication is that the different factors that operate within the nested genetic, biological, behavioral, social, and economic contexts change as a person develops (*Healthy People 2020*, 2010).

The Life Course Perspective

One of the essential features of the ecological model used in this text is that it integrates a life course perspective in its application to the epidemiology of aging. This approach is consistent with the current trends in public health practice and research, as noted by the *Healthy People 2020* (2010) report. One of the overarching goals in this report is the application of an ecological model that promotes "healthy development and healthy behaviors at every stage of life." The rationale underlying this application stems from the fact that the various determinants of health and the context in which they interact, including genetic, biological, behavioral, social, and economic factors, change as a person develops. Thus, a life course perspective is critical as we look to improve the health and quality of life of older adults and aging populations.

An Overview

A life course perspective examines the biological and behavioral pathways that link physical and social exposures during gestation, childhood, adolescence, and adult life to changes in health and disease risk later in life (Kuh, Richards, Cooper, Hardy, & Ben-Shlomo, 2013). Such a multidisciplinary framework helps us understand the importance of time and timing in associations between exposures and outcomes at the individual and population levels (Lynch & Davey Smith, 2005). This approach aims to consider the way that time and timing of various factors, such as physical growth, reproduction, infection, social mobility, and behavioral transitions, influence health and disease in older adults, and how these temporal processes are interconnected and manifested in population-level disease trends (Lynch & Davey Smith, 2005).

Historically, as research experience with a life course approach increased, particularly in the epidemiology of chronic diseases, various models were proposed. These models distinguished between critical or sensitive period models (with or without later-life modifiers) and risk accumulation models, attempting to identify both the timing and the type of exposures and to determine when in the life course these exposures "get under the skin" and leave biological imprints that later may manifest as adult chronic conditions (Kuh & Ben-Shlomo, 2016).

Essentially, these models represent the mechanisms by which exposures are believed to influence the development of health and disease over the life course (*Healthy People 2020*, 2010). In the critical periods model, the biological or behavioral systems are "programmed" during periods of high sensitivity. It is hypothesized that specific exposures (such as low birth weight) during times of rapid growth and development affect the risk of disease later in life by adjusting the structure or function of organs, tissues, and body systems (Kuh & Ben-Shlomo, 2016). Later risk factors may or may not modify these biological imprints.

The risk accumulation model proposes that the exposures and their effects accumulate over the life course, like weathering of the landscape over time. Such a model suggests that adverse exposures at any stage in life cause biological system damage, which then manifests as chronic disease later in life. An alternative explanation is that a sequence of these exposures ("chain of risk") accumulates, but it is the final event that causes damage to health (Kuh & Ben-Shlomo, 2016).

A third important mechanism influencing these models is the concept that there is a pathway process whereby factors in the social and physical environment reinforce other influences (*Healthy People 2020*, 2010).

What Is It?

The *Healthy People 2020* (2010) report states that an important aim of studying social and physical environmental factors is to increase health equity. To do so, it is necessary to recognize the substantial, often cumulative effects of socioeconomic status and related factors on health, functioning, and well-being from birth throughout the life course. These effects occur across all ecological levels (individual, social and physical environmental, societal).

There are two distinct approaches to studying human development over the life course: the "life stages" approach and "developmental stages" approach. These approaches are complementary and overlapping. Life stages are used to divide the life course into discrete blocks (e.g., infancy, childhood) to facilitate monitoring. Thus, the life stages approach is cross sectional, and it offers a way to break up the life course into easily measured stages (*Healthy People 2020*, 2010). In contrast, the developmental stages approach is longitudinal, and offers a way to examine the impact of early life experiences and exposures on health status later in life.

An important development in the epidemiology of aging is the idea that there is much to be learned by studying the whole spectrum of health and aging, from those individuals who are aging well and have the best health (i.e., the highest-functioning individuals) to those who have the worst health or are experiencing accelerated aging (Kuh et al., 2013). This notion introduces two concepts based on the fact that any research or studies performed on older populations are done on the survivors who have lived long enough to get old: (1) Individuals may have an intrinsic functional or structural reserve, and (2) There may be a compensatory reserve based on the resilience of the individual.

FIGURE 2-2 illustrates the notion of a functional or structural reserve by showing the functional trajectories of body functions and

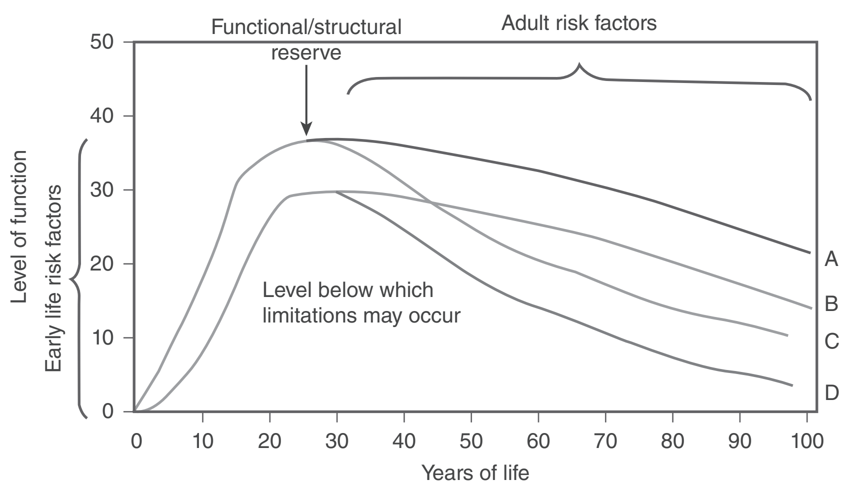

FIGURE 2-2 Functional trajectories of body functions and structures over the life course

Reproduced from: Kuh D, Richards M, Cooper R, Hardy R, Ben-Shlomo Y. Life course epidemiology, ageing research and maturing cohort studies: A dynamic combination for understanding healthy ageing. In: Kuh D, Cooper, R., Hardy, R., Richards, M., & Ben-Shlomo, Y., editor. A life course approach to healthy ageing: Life course approach to adult health series. Oxford: Oxford University Press; 2013. p. 3-15.

structures over the life course. Line A denotes the rapid growth and development during the prenatal, prepubertal, and pubertal periods, which reaches a peak or plateau at maturity. Line B shows how exposures and epigenetic mechanisms in early life, particularly during a critical developmental window, may leave imprints and have an effect on the structure or function of body systems. However, they may not have any appreciable effects on the rate of decline. Line C, in contrast, shows the accelerated aging processes leading to a more rapid functional decline. Finally, line D shows how various adverse exposures across the lifespan may affect the reserve and accelerate functional decline (Kuh et al., 2013).

An important question in the epidemiology of aging is why some people age better than others. One concept that complements a life course perspective and ecological model is the idea of **resilience**. We must consider the following questions when pondering the effects of resilience:

- To what extent is resilience determined by the ecological level—that is, by community, individual, and biological characteristics?
- How can resilience be developed, maintained, and enhanced to reduce health and social inequalities and achieve healthy aging across the life course?
- Can resilience be defined and measured so it informs research, policy, and practice?
- How do life course experiences influence health and resilience?

The Importance of Place

While the ecological model stresses the importance of considering all levels affecting an individual, and a life course perspective tells us that these levels must be taken into account at all stages in life, most studies looking at healthy aging have traditionally focused on the role of individual factors in encouraging or preventing outdoor mobility such as functional status, self-efficacy, and outcome expectations (Kerr, Rosenberg, & Frank, 2012). Until relatively recently, research focusing on enabling older adults to age in place did not consider the importance of "place," especially the built environment.

This was not always the case. The public health profession originated in tandem with the city and land use planning profession; indeed, for much of the late 19th and early 20th centuries, they were almost united and were closely allied with the social welfare movement. The seven founders of the American Public Health Association in 1872 included an architect and a housing specialist (Jackson, Dannenberg, & Frumkin, 2013). Gains in life expectancy were to a great extent due to improvements in the built environment, including better and healthier housing, street design, and access to clean water, food, and air. With the advent of clinical medicine, the focus for much of public health shifted to interventions targeting individual diseases—both infectious and (later in the century) chronic. For the planning profession, the focus shifted to community design practices that were based on facilitating automobile travel (Kerr et al., 2012). This urban design strategy prioritized developing communities with lower residential densities and disconnected street networks with the purpose of preventing cars from traveling through neighborhoods. As a consequence, residential areas lost access to areas of employment, retail, and entertainment, making walking to these venues difficult for residents, especially older adults.

Nearly a century later, as the effects of these earlier decisions have become manifest, the idea that neighborhoods affect health has become widely accepted among researchers and policy makers (Yen, Michael, & Perdue, 2009). Community design that was supposed to promote public health, safety, and welfare has resulted in declining levels of physical activity and active transportation at a time when chronic diseases such as obesity and cardiovascular disease (CVD) are on the rise.

PEARL 2-1 Transdisciplinary Approach to Collaboration

A transdisciplinary approach to research and health interventions has become a requirement for obtaining funding from many governmental and grant funding organizations. These organizations realize that complex problems require an approach that encourages close collaboration between people in professions who do not necessarily share common academic homes (departments), language, concepts, and methods (Sallis et al., 2006). The partners must strive to understand and solve complex problems in the life-world, and view the complexities of the whole project, rather than one part of it. By transcending their own disciplines to inform one another's work, capture complexity, and create new intellectual spaces, the members of such transdisciplinary teams can potentially stimulate innovation in a broad range of disciplines (Roux, 2007; Sallis et al., 2006; Wiesmann et al., 2008).

With this realization has come a growing collaboration between the planning professions and public health professionals. This requires increased integration of public policy, architectural, and environmental leadership to create age-friendly urban environments and social institutions and roles for older adults that promote health through continued engagement (Fried, 2016). In addition, advocacy may be an effective strategy to encourage cities' adoption of innovations that affect the mobility and quality of life of older adults by emphasizing potential financial benefits to the city, and focusing on cities whose aging residents are particularly vulnerable to disease and disability (Lehning, 2012; Scharlach & Lehning, 2013).

The research examining the connection between the neighborhood environment and older adults' health and functioning is still very limited. A comprehensive literature review suggested the need for additional hypothesis-driven research based on models linking specific neighborhood exposure to health outcomes in older adults, new methods that define and measure "activity spaces" that are relevant to older adults, and integration of direct measurements of these spaces into research (Yen et al., 2009).

Why is this important in the study of epidemiology of aging, and specifically to the area of healthy aging? A landmark WHO (2015) report, *World Report on Ageing and Health*, assembled nearly 200 experts to outline a public health framework for action on healthy aging that is built around the concept of functional ability. In the report, this framework is defined as "the health-related attributes that enable people to be and to do what they have reason to value." This ability is, in turn, determined by both the intrinsic capacities of individuals and the influence of the environments they inhabit (Beard, Officer, & Cassels, 2016). Living longer cannot be the ultimate goal of public health if the extra longevity does not result in added years that are lived in good health and an aging population that becomes a growing human resource that can contribute to society in many ways, such as through a longer working life and the generative social capital of older adults, the "third demographic dividend" (Fried, 2016). This combination would contribute to stronger and wealthier societies, which in turn would benefit the young and increase society's ability to provide the humane supports needed at the end of life (Fried, 2016). Diminishing limitations in capacity for older adults to age in place while achieving their best possible health outcomes makes both societal and economic sense by diminishing demands for health care and social care and increasing the contributions that older adults can make.

When authors of other chapters in this text consider outcomes such as falls or mobility limitations and barriers, the notion of place is implicit in the entire narrative. As an example, it has been shown that when older adults have poor lower-body function, those who have less proximity to goods and services and report more barriers to walking experience more mobility disability compared to other older adults (Satariano et al., 2014).

In conclusion, the built environment influences the mobility of older adults, especially their physical activity. Addressing only intrapersonal ecological factors such as self-efficacy or social support without considering built environment factors such as walkability and access to recreation and services is much less likely to result in a physically active, mobile, and cognitively healthy older population (Carlson, Sallis, & Conway, 2012; Yen et al., 2009). It is hypothesized that built environment factors such as land-use patterns, esthetics, the accessibility and connectivity of urban design, housing quality and population density, pedestrian-friendly environments, and parks are all variables that may greatly affect the physical activity and patterns of mobility among older people (WHO, 2015). As yet, this area has not been studied with the significant attention it deserves.

Resilience Later in Life

The concept of resilience is largely based on the general systems theories elaborated by von Bertalanffy (1968) and others. It was later developed and applied independently in the fields of ecology and psychology as a way of looking at systems of many kinds at many interacting levels, both living and nonliving, such as microorganisms, economies, children or families, a forest, or the global climate (Garmezy, 1971; Holling, 1973; Masten, 2014). Resilience is defined broadly as the capacity of a dynamic ecosystem to respond to a perturbation or disturbance by resisting damage and recovering quickly. In ecology, examples include the ecosystem's stability and capability of tolerating disturbances and restoring itself after fires, floods, deforestation, or fracking, for example. In psychology, particularly child development, the concept has deep roots in the aftermath of World War II, an event that exposed children and youth to severe traumatic experiences (Masten, 2014). Early research in resilience and public health looked at protective factors in the area of developmental psychology (Garmezy, 1973; Werner, 1989; Werner, Bierman, & French, 1971). As the concept was applied to other populations, it became important to define resilience as a process that can be learned and developed, rather than an individual trait.

An ecological model and a life course process are suggested by the fact that the resilience response process unfolds over time and is embedded within the context. Indeed, it has been explicitly proposed that resilience should be placed in an ecological model that applies to individuals and their communities in later life (Aldwin & Igarashi, 2012). The study of resilience has been influenced by Bronfenbrenner's (1979) ecological model, which considers development "a person's evolving conception of the ecological environment, and his relation to it, as well as the person's growing capacity to discover, sustain, or alter its properties" (p. 9).

Resilience results from the ability of individuals facing stress or adversity to effectively use coping mechanisms in a process that promotes well-being. This method of adaptation may be particularly important in the face of the accumulation of risk factors over the course of a lifetime—that is, within the risk accumulation model, in which the cumulative risk factors result in chronic disease. With roots in the Latin verb *resilire* ("to rebound"), the concept of resilience has been adopted by social scientists to understand how some people escape the harmful effects of severe adversity, cope well, bounce back, or even thrive (Masten, 2014). The study of resilience focuses on one particular subset of processes associated with human development: those that enhance the experience of well-being among individuals who face significant adversity (Ungar, Ghazinour, & Richter, 2013). Thus the importance of the idea of resilience in the study of healthy aging that is explored in other chapters of this text.

Resilience later in life has been equated by Hochhalter, Smith, and Ory (2011) with successful or optimal aging that "leaves one ideally positioned to reach his or her goals." Adaptation occurs throughout the lifespan and has been described as active aging, defined by WHO as "the process of optimizing opportunities for health, participation, and security in order to enhance quality of life as people age" (Mutangadura, 2004, p. 12). While the concept of successful aging, as originally adopted by Rowe and Kahn (1997), helped focus on the idea that some people were better than others at progressing through the aging process, there has been some criticism that this perspective may stigmatize people with chronic disease as being "unsuccessful" in aging.

As we discuss in the next section, the epidemiology of aging, health, functioning, and longevity should be based on a perspective that considers the influences at multiple levels and that reflects the significant and dynamic interrelationships of those different levels of health determinants. This must be embedded in a life course perspective because the outcomes in later life can be linked to exposures in earlier life of individuals and populations.

Epidemiology of Aging

In this section, we examine in greater detail some components of the various levels of the ecological model. Some of the most powerful determinants of health, which include genetic, behavioral, social, and environmental factors, are closely interconnected. **FIGURE 2-3** depicts the range of variables from the ecological model as being divided into three sections (circles). It is important to stress that these variables are interrelated; in other words, each variable affects and, in turn, is affected by each other variable. The model does not, however, imply specific, hypothesized causal relationships or causal links across independent, intermediary, and dependent variables. It is intended to serve as a graphic representation that can help guide our consideration of research in the epidemiology of aging.

In the first part (top circle) of Figure 2-3, we consider some of the more traditional components of epidemiology, while paying special attention to aging individuals and populations. These components include demographics such as age, gender, race and ethnicity, and socioeconomic status (SES). We then look at some of the social determinants of health such as social capital; the built environment (BE), physical environment, and living arrangements; social networks; and social support, which constitute a broader level of the ecological model. In the second part (middle circle) of Figure 2-3, we focus on more specific health behaviors known to exert major health effects on individuals and populations, such as tobacco exposure, alcohol consumption, physical activity (PA), diet and nutrition, and cognitive activity. Over the life course, the outcomes that are displayed in the second circle also may affect the variables listed in the first circle. The third circle represents vital status (alive or dead).

Epidemiology of Aging Research

In 1984, the WHO report *The Uses of Epidemiology in the Study of the Elderly* pointed out the existence of major gaps in knowledge about the state of health of elderly populations, even in the richest countries, and noted that these gaps were due in part to the problems of conceptualization and definition of health and to the difficulties of measuring it. Given that the purpose of health and social services directed toward this population is to improve the health and promote the well-being of the elderly, WHO suggested that health and well-being should be operationally defined, with the factors that affect these outcomes being ascertained and measured.

This conclusion was the direct result of the surprising lack of epidemiological research focusing on aging until the early 1980s (Davies, 1985). Although it was clear that the complex and intertwined causes and consequences of aging of populations demand an interdisciplinary approach, including input from the field of

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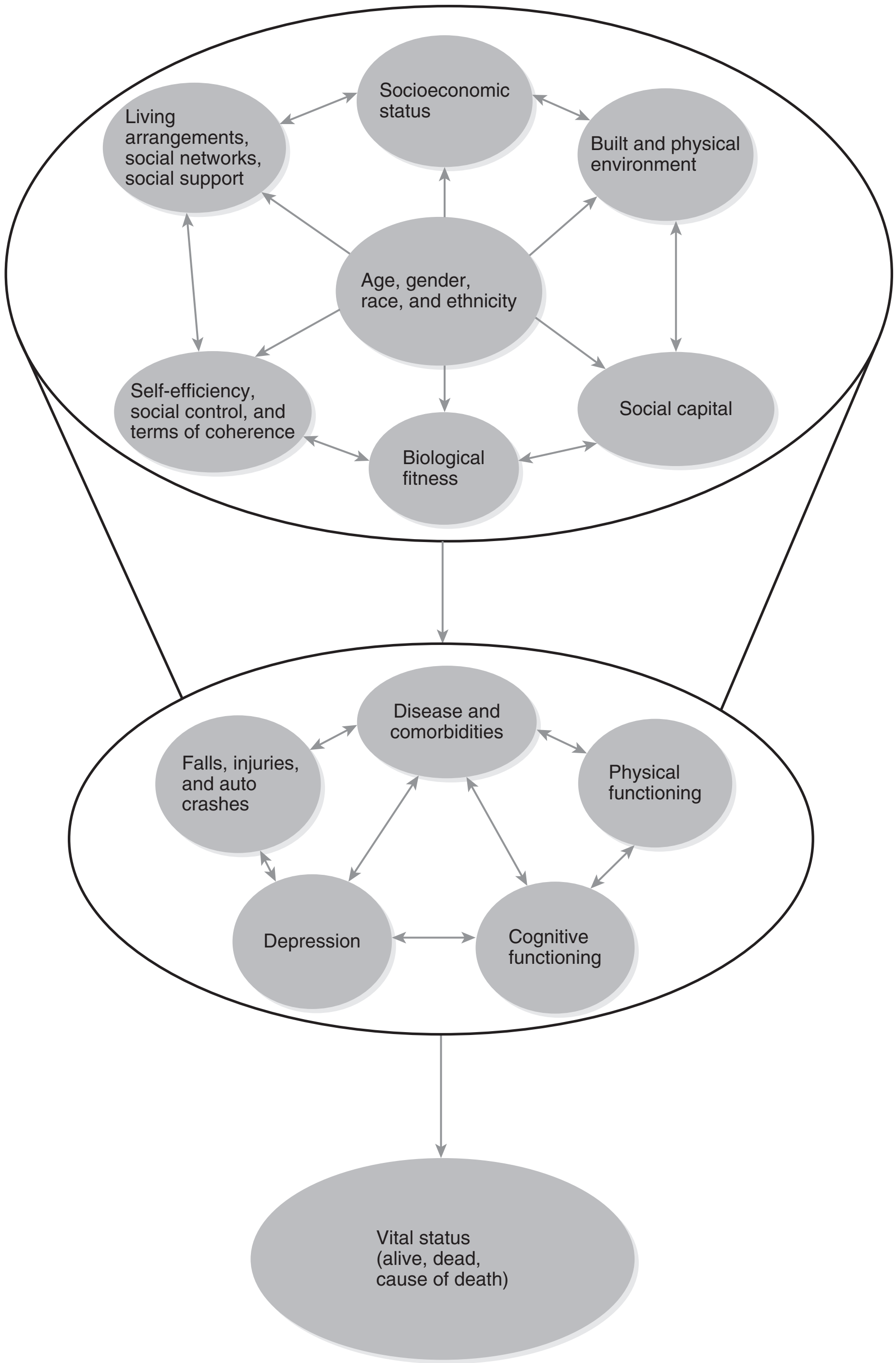

FIGURE 2-3 The range of variables from the ecological model

Reproduced from: Satariano W. Epidemiology of aging: An ecological approach: Jones & Bartlett Learning; 2006.

epidemiology, most of the advances in **aging research** were made in separate scientific disciplines, such as cellular aging, sociology of aging, demography, and physiological, psychological, or economic areas; only few attempts at integrated or holistic approaches were made (Brenner & Arndt, 2004; Davies, 1985).

It is through the application of epidemiological methods to research related to aging individuals and populations that understanding of the need for, and some proposals of, appropriate definitions for this evolving field emerged. Epidemiology must play a major role in elucidating the determinants of health necessary for the elderly to remain healthy and independent so that they can continue to play an active role in society. Measures of health are difficult to obtain at any age; however, they become especially complicated with advancing age. It has been proposed that the maintenance or restoration of autonomy and independence are the ultimate measurable goals in this population. Thus, autonomy can be used as a reasonable proxy for health, albeit attended by further difficulties in attempting to define the concept operationally.

As defined by the Centers for Disease Control and Prevention (CDC), epidemiology is the study of the distribution and determinants of health-related states or events in specified populations, and the application of this study to the control of health problems (Dicker, Coronado, Koo, & Parrish, 2006). Who is affected and which specific factors put individuals at risk are key questions that researchers must address. Studies are usually distinguished as consisting either of descriptive epidemiology or analytical epidemiology. Descriptive epidemiology is concerned with the observational study of the occurrence of disease and other health-related characteristics in human populations. It deals with general descriptions concerning the relationship of disease to basic characteristics such as age, gender, race, occupation, social class, and geographic location (Porta, 2008). In the case of older adults, the incidence of functional impairments is a particularly important measure, in addition to other measures such as mortality and prevalence of diseases or impairments.

For many chronic diseases and functional impairments, their incidence, mortality, and prevalence increase with age, and they often vary by sex even within the same age groups. Given this reality, it is important that measures be reported by age and sex (Brenner & Arndt, 2004). It is critical to avoid possible biases from changes in the age structure of populations over time or from the various populations being compared. To accomplish this goal, age-standardized measures of incidence, mortality, and prevalence may be used that assume a common fixed age structure of some "standard population," such as the world population, or some regional or national population.

While descriptive epidemiology can be used to generate hypotheses, testing those hypotheses requires the application of analytic epidemiology. Analytical epidemiology is used to identify the quality and the amount of influence that determinants have on the occurrence of disease or functional impairment. The usual way to gain this knowledge is by group comparisons using either case-control studies or cohort (longitudinal) studies.

Cohort studies are of particular importance in the area of the epidemiology of aging because they allow for the assessment of etiologic factors of multiple health outcomes that are encountered very frequently in the settings of comorbidity and multimorbidity common in older adults. It is also suggested that the quality of data on risk factors or protective factors is often superior in cohort studies, since this information is collected prospectively, rather than retrospectively as in case-control studies (Brenner & Arndt, 2004). In addition, the cohort approach is more effective in suggesting causal effects by providing stronger evidence regarding the temporal relationship between the occurrence of presumed risk and/or preventive factors and the health outcome.

Observational studies are prone to the bias associated with confounding, which occurs when all or part of the apparent association between the exposure and the outcome is actually accounted for by other variables that affect the outcome and are not themselves affected by exposure (Porta, 2008). For example, various lifestyle factors, such as dietary habits, physical activity, smoking, and alcohol consumption, which are clearly related to a variety of health outcomes at old age, are often interrelated with each other (Brenner & Arndt, 2004). To address this possible bias, the other factors, as well as additional relevant factors such as age or gender, are carefully measured and controlled for in the analysis. Control for confounding is typically done by means of analytic methods such as multivariate analysis or other statistical models.

Health Behaviors

As we have previously argued, an integrated ecological life course model of aging considers that social and biological factors across life affect the probability of healthy aging. The demographic transition to greater life expectancy and the resultant older population is the result of many factors including better childhood nutrition, education, improvements in the environment, advances in medical science, public health, and lifestyle and behavior change. Health behaviors, such as physical activity, dietary practices and nutrition, tobacco exposure, and alcohol consumption, are especially associated with health, functioning, and longevity across the life course (Emmons, 2000). Such modifiable health behaviors could potentially be linked to as many as two thirds of all cancer deaths (Colditz et al., 2000).

Health behaviors play a central role in the life course model, acting in both the risk accumulation model and the "chain of risk" model that links exposures to impaired function. In short, the way we live (in terms of diet, physical activity, and area characteristics) has a direct effect on the likelihood of healthy aging, and life course influences determine the way we live (Kuh et al., 2013).

While very significant differences in life expectancy are apparent across the United States, studies show that the gap in lifespan between the rich and the poor has increased significantly in recent years. For poor Americans, where they live in the United States plays a key role in determining how long they live, while higher income is associated with greater longevity (Chetty et al., 2016). The differences in life expectancy have remarkably increased across income groups over time. Even so, the association between life expectancy and income varies substantially across areas; differences in longevity across income groups have decreased in some areas and increased in others. We now realize that life expectancy is correlated not only with health behaviors, as was traditionally the focus of public health interventions, but also with local area characteristics. The importance of place—of residential areas and the built environment in general—is an essential characteristic of the ecological model and life course perspective because "place" clearly possesses both physical and social attributes that can affect the health of individuals.

To investigate multiple different health outcomes, including chronic disease, morbidity and mortality, mental health, infant health, and birth outcomes, analytical techniques such as multilevel analysis are employed to study neighborhoods and the individuals who live in them (Pickett & Pearl, 2001). In accordance with the framework used in this text, this approach seeks to reconcile two divergent epidemiological paradigms—individual risk factor epidemiology and an ecological approach (Roux, 2007).

In the past, most studies looked at the association of place and specific diseases such as cancer, hypertension, or cardiovascular disease (Cubbin & Winkleby, 2005; Roux et al., 2001). More recently, other indicators have emerged, especially in the area of healthy aging, focusing on physical and cognitive capability (Murray & Stafford, 2014). One important aspect of studying the built environment is the measures used to describe it. These can be subjective, based on the perception of the environment by either the inhabitants or outside observers, or it can be objective, as when research relies on census data or observational measures of the actual buildings and streets and land-use records. An example of a self-reported function in older adults and their environment is an Alameda County study that looked at older adults experiencing severe difficulty with physical tasks (e.g., climbing stairs or lifting 10 pounds) (Balfour & Kaplan, 2002). As with all self-reported data, there is a risk of bias in studies that collect such data because the subjects may consistently over- or under-estimate the objective measures of the environment. One exception has been research of crime rates, where perceptions of safety and actual reported crime statistics have had a significant correlation with disability ("going-outside-the-home disability") (Beard et al., 2009).

Most studies looking at the association between cognitive functioning of older adults and the environment have primarily examined the socioeconomic characteristics of the environment (Murray & Stafford, 2014). Very few studies have looked at cross-sectional links between census-derived data and different tests of cognitive functioning. These links may include differences in cognition between individuals of high and low educational attainment as related to individual and environmental conditions. Showing that cognition varies across urban neighborhoods suggests that social context is an important factor in determining cognitive function among older adults (Wight et al., 2006).

The association between the residential area inhabited in childhood or early adulthood and healthy aging in later life is a major component of a life course approach and one that affects how communities are designed. Various international reports have stressed the importance of healthy and active aging and its relationship to external factors including the built environment (WHO, 2002, 2003a). The effects of human-made and natural environments (and the interactions between the two) on the development of chronic diseases are increasingly being recognized. Ideally, we would design communities specifically for active aging, so that the community-based effects would take place throughout the life course. Furthermore, there is a need to understand how human-made environments affect us physically, and how these structural factors can help promote healthy active aging in populations with increased longevity.

Probably one of the most important modifiable health behaviors affecting healthy aging over the life course is physical activity—or more correctly, as WHO (2016) has indicated, physical *in*activity. WHO attributes approximately 3.2 million deaths each year to insufficient physical activity,

PEARL 2-2 Tobacco Control and Behavior Modification

Smoking is an important modifiable risk behavior that affects all other health outcomes in an older population. Although older people are less likely to smoke than younger people, in 2010 fewer than 10% of older people smoked, compared to almost 20% of younger people. Older adults who smoke face an elevated risk of health problems compared with those who do not smoke (West, Cole, Goodkind, & He, 2014) because older people typically have a longer history of tobacco use, are heavier smokers, are already suffering from smoking-related health conditions upon entering older ages, and have other comorbidities (Burns, 2000). Smoking remains a strong risk factor for premature mortality at older age, and smoking cessation is beneficial at any age (Gellert, Schöttker, & Brenner, 2012).

Studies show that residents living in resource-poor areas, such as those characterized by substandard housing conditions, differential access to health services, and lack of social organization, have a higher prevalence of smoking independent of individual social class and educational level (Shohaimi et al., 2000). The ecological model has become a key feature in the planning of interventions for tobacco control (Sallis et al., 2006).

with many developed and developing countries having populations in which as much as 50% of the adults are insufficiently active. In terms of both human and economic costs, the public health burden of inactivity is very significant, as mortality and chronic conditions tend to negatively impact quality of life as well as life expectancy for inactive individuals. Unfortunately, the growing levels of both inactivity and obesity pose (independent) major health problems in Western society (Colditz, 1999).

To understand how older adults are involved in physical activity, it must be realized that certain trends are associated with aging. Physical activity levels decline by age in adulthood and, in general, men are more active than women across all age groups (Ekelund, 2014). Most of these observations appear generalizable across cultures and ethnic groups, regardless of whether physical activity has been assessed by self-report or objective measurement.

In a comprehensive review of the available time-trend data from the United States, the following trends were observed with greater age, according to the type of physical activity:

- Relatively stable or slightly increasing levels of leisure-time physical activity
- Declining work-related activity
- Declining transportation activity
- Declining activity in the home
- Increasing sedentary activity

Collectively, these trends result in an overall trend of declining total physical activity (Brownson, Boehmer, & Luke, 2005). Causes of these trends may include changes in the built environment, such as urbanization, and an increasing proportion of the overall population being sedentary.

Cognitive ability in older adults reflects the interplay of various factors, including the baseline physical fitness from which adults progress and the level of activity they perform during the life course. Better fitness at baseline is associated with better cognitive function in healthy older adults, particularly on measures of global function and attention/executive function (Barnes, Yaffe, Satariano, & Tager, 2002).

Maintaining cognitive ability as a way to promote healthy aging may depend on a combination of various approaches. An increasing body of evidence suggests that physical exercise has beneficial effects on cognition by enhancing neuroplasticity, thereby preventing cognitive decline and pathological aging (Bamidis et al., 2014; Williams & Kemper, 2010). Combining physical activity with cognitive training might result in a mutual enhancement of both interventions and increased maintenance of cognitive ability due to the increased cardiovascular fitness level. The underlying mechanism might be the enhancement of an individual's capacity to respond to new demands with behavioral adaptations (Hötting & Röder, 2013).

A very exciting area of research is the use of technology to encourage physical activity in combination with cognitive training. Various reports suggest that simultaneous physical and cognitive exercise induce more beneficial cognitive effects than purely cognitive and physical interventions provided separately (Bamidis et al., 2014; Konstantinidis et al., 2012). An adaptation of so-called exergame training, which combines cognitive and physical activities in a game format, might be an effective way to promote physical and cognitive improvements among older adults (Maillot, Perrot, & Hartley, 2012). Using mobile technology to promote walking outdoors in a safe environment (such as parks or safe streets) and combining it with a cognitive intensive activity (such as a word game) in a group setting that also stimulates social interaction is another approach to increasing the physical activity of older adults (Satariano & Maus, 2016). Making physical activity accessible, fun, and safe by taking advantage of the rapidly advancing mobile technology may turn out to be one of the great success stories of the technological revolution of the 21st century.

WHO (2003a) has recognized that chronic disease must be seen in the context of the life course in the same way that both under- and over-nutrition, in addition to other factors mentioned previously, play a role in the development of chronic disease. The global epidemic of increasing obesity, diabetes, and other chronic noncommunicable diseases, for example, is affecting all economies—developing and transitional economies, less affluent segments within these regions, and developed countries. At the same time, an increasing number of communities and households have coincident under- and over-nutrition. Although genetic predisposition and fetal life programming do play roles in these phenomena, the most readily apparent association with the obesity/diabetes/chronic disease epidemic is a lifetime of exposures and influences (Darnton-Hill, Nishida, & James, 2004). A life course approach to research into dietary habits, particularly if focused on the period of life when food preferences are formed and in which families have constrained access to nutritionally adequate diets, has clear implications for designing nutrition interventions and educational programs (Wethington, 2005).

In conclusion, two of the most significant risk factors for poor health outcomes in older adults in terms of the life course are diet and physical activity. Their relationship to the human-driven changes in the physical environment and the aging of the world's population require that the modifiable social and environmental factors be addressed in both the study of the epidemiology of aging and the planning of public health interventions.

Measures

Global Burden of Disease. The global burden of disease (GBD) is an important measure used in international epidemiology, as it allows us to compare diseases, injuries, and risk factors, and to understand in a given place, time, and age–sex group which factors might make the most important contributions to health loss (Murray et al., 2012). GBD has particularly useful applications in studies of aging populations, given that 23% of the total global burden of disease is attributable to disorders in people aged 60 years and older, especially in the high-income regions (Prince et al., 2015). Nevertheless, it has also been reported that per-capita disability-adjusted life-years (DALYs) are 40% higher in low-income and middle-income regions (Waddington, 2012).

Health, Functioning, and Longevity: Healthy Aging. The remaining components of the ecological model include measures of health, functioning, and longevity. With the exception of longevity and vital status, each of the measures of health and functioning serve both as outcomes and predictors. Other chapters of this text examine specific health outcomes, including mortality and causes of death.

Conclusion and Future Directions

The ecological model assumes that patterns of health and well-being in human populations are associated with a dynamic interplay of biologic, behavioral, social, and physical environmental factors—an interaction that unfolds over the life course of individuals, families, and communities. Using this model enables us to represent a very complex set of factors and problems. We have come to realize that complex problems require an interdisciplinary approach and even a transdisciplinary approach. This kind of multifaceted approach, rather than just relying on increased innovation in the methods used within a single type of study, will be essential if we are to continue to advance our understanding of, and find solutions to, these problems. Given the high prevalence of multimorbidity during old age, a clinical approach that considers a single diagnosis

PEARL 2-3 Epigenetics

An exciting field that is developing due to the advances in genomics is "epigenetic epidemiology." The term *epigenetics* is described in a landmark article by Conrad Waddington (2012), in which he postulated that "between genotype and phenotype, and connecting them to each other, there lies a whole complex of developmental processes," the so-called epigenotype. This field offers the promise of "prediction, prevention, and treatment of a wide spectrum of common complex diseases" (Relton & Davey Smith, 2012).

Since epidemiology is concerned with group-level analysis, it can provide the much-needed methodology to identify the major determinants of epigenetic variation and their suggested contributions to health and disease. To accomplish this, it has been suggested that traditional epidemiology methods—such as population-based studies, twin studies, family-based studies, cross-sectional studies, and especially longitudinal cohort studies—will be applied to this new interdisciplinary field (Ng et al., 2012; Relton & Davey Smith, 2012).

in the epidemiology of aging would be too restrictive and would most likely fail to produce the desired studies and applications. Health outcomes cannot be simply considered separately, but rather development of new methods is required to adequately deal with multiple, complexly interrelated health outcomes (Brenner & Arndt, 2004).

Other suggestions for future directions in the epidemiology of aging include increased use of birth cohorts and other cohort studies under a life course perspective, the emergence of the field of epigenetic epidemiology, and the design of studies specifically for older populations rather than extrapolating based on younger populations.

Finally, by using the principles of epidemiological aging research, we can help create the solid scientific base necessary both to address the burden of disease in older populations and to promote healthy aging. We hope that this model will serve as the map that guides researchers, practitioners, and students in reviewing and evaluating the concepts, methods, and research in the epidemiology of aging.

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