Chapter 5

Social-ecological model of sleep health

Michael A. Grandner

Sleep and Health Research Program, Department of Psychiatry, University of Arizona College of Medicine, Tucson, AZ, United States

INTRODUCTION

Insufficient sleep duration and/or poor sleep quality represents a significant, unmet public health problem [1]. In epidemiological studies, spanning over 40 years and multiple continents, short and/or long sleep duration, as well as poor sleep quality, is associated with increased mortality risk [2, 3]. Additionally, insufficient and/or poor quality sleep is associated with (and thought to play a causal role in) 4 of the 7 leading causes of death, including heart disease, stroke, accidents, and diabetes, as well as other important health outcomes, such as weight gain and obesity, depression, and cognitive deficits. Current research is exploring mechanistic aspects of these relationships, such as isolating genetic vulnerabilities, identifying biomarkers for daytime sleepiness, and determining ways in which sleep plays a role in protective signaling pathways.

What these studies have in common is that they are exploring the "downstream" effects of sleep-related problems, clarifying how sleep plays a role in cardiometabolic disease, in addition to other adverse health outcomes, and how these pathways may explain the well-documented relationships with mortality. Increasingly, attention has focused on determinants of sleep—"upstream" influences that play a role in the development of the problematic sleep patterns that are predictive of worse health. A better understanding of the determinants of sleep will aid in the identification of modifiable factors and intervention targets that can be manipulated. For example, as poor diet is known to be associated with a number of negative health states, understanding the determinants of obesity (e.g., advertising, access to healthy food, socioeconomic status, sedentary lifestyle) has identified useful targets for change.

Accordingly, this chapter proposes a theoretical model for considering insufficient and/or poor quality sleep in the context of its associated negative health outcomes (e.g., obesity, diabetes, cardiovascular disease, depression), as well as its likely determinants. Since there is sparse literature on determinants of sleep, we constructed our model with input from existing models for other health behaviors (e.g., diet, exercise). These models are typically based on a Social-Ecological framework, which conceives of a behavior of interest (e.g., a person's diet) in the context of individual-level factors, which are embedded within social networks (e.g., family, work), which are themselves interrelated and embedded within larger networks (e.g., community, religion), which exist in a context of society that influences these networks in a number of ways (e.g., laws, technology, economics). Using a traditional Social-Ecological approach as a starting point, we constructed our model as a series of embedded systems (Individual Level, Social Level, and Societal Level), identifying key components of those systems believed to be determinants of sleep.

In summary, this model presents a conceptual framework for the "downstream" negative effects of insufficient and/or poor quality sleep, as well as the "upstream" determinants. The upper part of the model (determinants) is constructed based on existing theoretical models for other health behaviors, focusing on aspects thought to be particularly germane to sleep. The second part of the model (outcomes) is constructed as a synthesis of available data from epidemiological and experimental studies. Together, the model considers a global view of sleep and health, establishing a framework for future research to explore the determinants of sleep from a societal standpoint. Future studies will add clarity to the model, discerning unique and combined influences from the Individual, Community, and Society levels. Finally, interventions developed based on this model can address problematic sleep at the Individual (e.g., improving an individual's sleep), Social (e.g., promoting workplace initiatives that minimize sleep-related impairments or increasing healthy sleep habits in families), and Societal (e.g., public policy initiatives and educational campaigns) levels.

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THE SOCIAL ECOLOGICAL MODEL

The Social-Ecological Model was originally proposed by Bronfenbrenner [4]. This model was intended to conceptualize the role of the individual in their environment. A key feature of this model is that the individual exists at the center of a nested set of constructs that describe levels of the environment in relation to the individual. The idea is that each level is nested within the next, and so on. A schematic of the main components of the model is displayed in Fig. 5.1. First, the model starts with the individual. Each individual person is believed to exist within their own specific social-ecological framework of nested systems.

The first layer beyond the individual is the "microsystem." This is the system in which the individual is embedded. According to this model, the microsystem refers to the set of interactions between the individual and elements of their environment at home, at school or work, etc. These are specific environments that the individual interacts with. In each of these environments, the individual takes on a specific role (e.g., mother or father, worker, son or daughter, teacher, friend) for specific periods of time. A key element of the microsystem is that this is where the individual specifically acts in relation to those around them.

The next layer around the microsystem is the "mesosystem." Just as the individual is embedded within the microsystem of people, places, and roles, the microsystem is itself embedded within the mesosystem. This system describes the interrelations among elements of the microsystem that are outside of the individual. For example, the interactions of a child at home with their parents and at school with their teachers exist within the microsystem, but the parent-teacher meeting would, for example, exist within the mesosystem. The mesosystem represents the collected microsystems of the other people that the individual interacts with in their own microsystem.

The next layer around the mesosystem is the "exosystem." This system of interactions encompasses elements of the mesosystem that do not specifically interact with the microsystem of the individual. For example, the neighborhood, a person's industry, the media, the consumer landscape, and the communication system of mobile phones represent discrete and conceptual members of the exosystem. The exosystem is the milieu within which the mesosystem exists. It represents the interactions and human processes that facilitate, hinder, control, or modify elements of the mesosystem (e.g., a company or a school) that then influences the microsystem (e.g., a workplace or a classroom), which influences the individual.

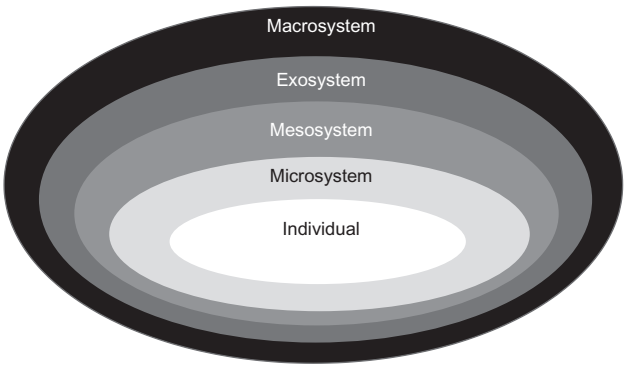

FIG. 5.1 Social-ecological model.

Beyond the exosystem, which exists outside of the mesosystem, is the "macrosystem." The macrosystem includes the constructs within which the exosystem exists. The mesosystem rarely includes specific entities (as these would likely exist in the exosystem). Rather, the macrosystem reflects the common ideas, expectations, prototypes, and stereotypes that guide the exosystem. For example, there are sets of ideas in a culture about how a workplace should be, which influences the exosystem of an industry, which influences a specific company, which influences a specific workplace, which influences a specific individual. Thus, the macrosystem is the most abstract of the layers of the social-ecological model.

This concept of embedded systems reflecting layers of abstraction (the social-ecological framework) has remained a useful construct in understanding health behavior. For example, it has guided the development of interventions for diet [5], physical activity [6, 7], substance abuse [8], stress management [9], vaccination [10], suicide prevention [11], environmental change [12], and other domains. It is possible that this model can also be applied to sleep, which itself is an important domain of health behavior.

SLEEP AS A DOMAIN OF HEALTH BEHAVIOR

The concept of a "health behavior" refers to a behavioral domain that can have broad impact on health, functioning, and longevity. This idea gained strength when it was found that behavioral factors were the leading "actual" causes of death in the United States in 2000 [13]. The leading "actual" causes of death were smoking, poor diet, lack of physical activity, and alcohol consumption, which accounted for >38% of all deaths combined. Insufficient and/or poor quality sleep was not considered in these analyses, but assessment of the mortality data for sleep duration and sleep apnea suggests that many deaths may be at least partially sleep-related. Further, insufficient and/or poor quality sleep has wide-ranging physiologic and psychological outcomes (described below). For these reasons, we propose that sleep represents a domain of health behavior.

Many studies have documented adverse physiologic, medical and psychological outcomes associated with habitual short sleep duration and experimental sleep deprivation (i.e., insufficient sleep duration), as well as poor sleep quality in general and sleep disorders such as insomnia,

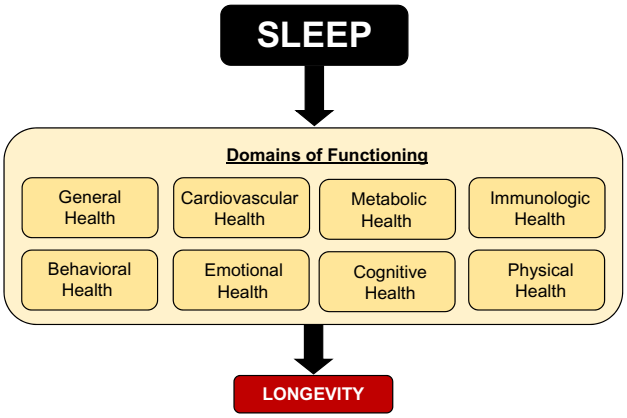

FIG. 5.2 Sleep as factor in health and mortality.

sleep apnea, and others (see other chapters in this volume). Accordingly, in building the model, we began with a proposed causal pathway linking sleep to adverse outcomes (Fig. 5.2). As depicted, the main domains impacted by sleep include general health, cardiovascular health, metabolic health, immunologic health, behavioral health, emotional health, cognitive health, and physical health.

Several studies have shown that habitual short sleep duration is associated with increased risk of hypertension, heart attack, and stroke [14]. In addition, short sleep duration has been associated with elevated cholesterol and inflammatory markers [15]. Habitual poor quality sleep has also been associated with elevated risk of cardiovascular disease [16]. Insomnia—especially in the context of short sleep duration—has been shown to be associated with elevated cardiovascular disease risk [17]. Regarding sleep apnea, a large body of literature describes very strong relationships between sleep apnea and cardiovascular function [18]. Although the primary mechanism proposed for this link is through intermittent hypoxia, there is evidence that the sleep fragmentation that occurs as part of sleep apnea is independently associated with negative effects (see chapter in this volume).

Many studies have also found that short sleep duration is associated with increased body mass index and/or risk of obesity [19]. These findings are supported by a growing literature of epidemiologic studies that demonstrate prospective weight gain associated with short sleep duration [20–22] and laboratory studies that show that sleep deprivation is associated with increased calorie intake (despite no difference in energy use) [23]. Although fewer studies have explored sleep quality in this regard, a number of studies have shown that sleep disturbance is associated with increased risk of obesity (see chapter in this volume).

The role of sleep in mental health is also well-established. Poor sleep is a well-characterized risk factor for stress and is related to dysregulation of neuroendocrine stress systems. Insomnia is a major risk factor for depression [24, 25] and is a core feature of nearly all psychiatric conditions. Poor sleep has been linked to suicide [26], as has insufficient sleep duration [27] and nocturnal wakefulness [28, 29]. There is a growing literature demonstrating the role of sleep in neuroaffective regulation [30, 31]. And sleep plays important roles in substance abuse disorders involving alcohol, nicotine, opiates, cannabis, and other substance use disorders.

The impact of sleep loss on cognitive functioning is well-characterized as well. Extensive work has demonstrated that sleep loss impairs attention and ability to remain vigilant [32]. Sleep difficulties have also been associated with processes such as working memory, executive function, and function in other neurocognitive domains [33]. This may underlie other findings showing that sleep loss impairs strategic decision-making [34], risk-based decision-making [35, 36], and work productivity [37].

Taken together, the findings described above describe associations between sleep and a number of outcomes. It should be noted that in Fig. 5.2, these outcomes are in a common box; this represents the many intercorrelations among these domains. It should be noted that the model also takes into account the many studies that have shown that poor health states cause disruptions in sleep—either by shortening sleep duration or worsening sleep quality.

CONCEPTUALIZING SLEEP IN A SOCIAL-ECOLOGICAL MODEL

The social-ecological model, outlined above, describes the individual as embedded within the microsystem within which they interact, which is embedded within the mesosystem in which elements of the microsystem interact, which is embedded within the exosystem which includes the structures that surround the mesosystem, and the macrosystem which includes the broader constructs that guide the social environment. For the purposes of the proposed model, sleep is conceptualized along a similar nested system. The proposed model conceptualizes the determinants of sleep to exist on three levels: the individual level, the social level, and the societal level.

INDIVIDUAL LEVEL

Fig. 5.3 shows the causal relationship between individual-level factors and sleep. These individual-level factors are conceptualized to reflect aspects of the individual that proximally and/or directly relate to that individual's sleep. These factors represent aspects of the individual that impact sleep, as well as cognitive and behavioral phenomena that impact sleep. This level contains all factors that could fit into this category. For example, this level could include individual genetics, beliefs about sleep, attitudes about sleep, sleep-related behaviors, aspects of individual physiology, health status, and sleep-related choices.

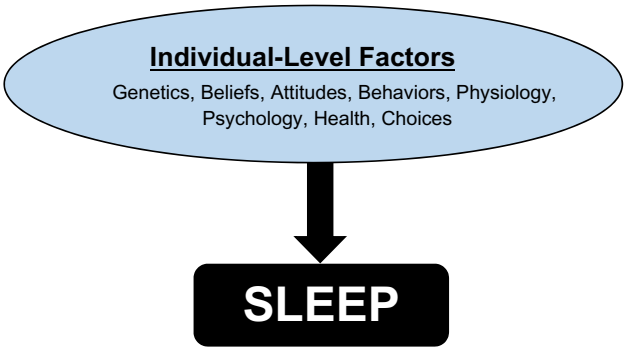

FIG. 5.3 Individual-level factors, sleep, and health.

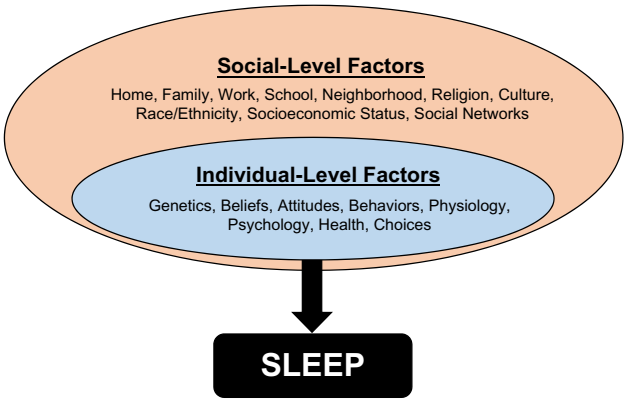

FIG. 5.4 Role of social factors in sleep and health.

An individual's genotype may exert influence over sleep in many ways. For example, genetics may influence circadian preference, sleep need, resilience against sleep loss, risk for sleep disorders, or even risk for other disorders that may impact sleep. Similarly, some aspects of physiology may impact sleep. For example, individuals who have lowered arousal thresholds may have more difficulty sleeping, as might those with disrupted neuroendocrine stress systems or even raised body temperature. Along these lines, health status is well known to influence sleep. Individuals may experience problems sleeping if they are ill, are in pain, have a sleep disorder, or another medical condition that interferes with sleep. Beliefs about sleep are also important factors at this level. Individuals who believe that they need less sleep, for example, may engage in more sleep-promoting behaviors. Previous studies have shown associations between sleep-related beliefs and sleep health [38], and changing sleep beliefs may impact on sleep-related behaviors. In addition to beliefs, individuals maintain attitudes about sleep. Those who express generally positive attitudes about sleep may be more likely to experience better quality sleep in general [39]. Further, these attitudes may be additional important contributors to behavior. An individual's sleep-related behaviors can encompass a wide range of possibilities, including sleep hygiene practices, bedtime routines, schedules maintained, etc.

Individual-level factors represent the proximal determinants of an individual's sleep, in a specific place, at a specific time. Some of these factors will represent aspects of the individual, some of these factors will represent aspects of the individual's current state, and some will represent aspects of what the individual is believing, thinking, and doing. These factors are conceptualized as generally time-dependent in that their influence on sleep depends on their characteristics at the time in which they exert influence. Genetics, for example, may not change, but beliefs may change, as might health conditions.

SOCIAL LEVEL

The proposed model conceptualizes the individual level factors as being embedded within social-level factors. These exist outside of the individual but include the individual. A construct exists at the social level if the individual is part of that construct but that construct would exist whether or not the individual exists. For example, work represents a social level construct, as the workplace represents a construct that contains the individual but would theoretically exist without them. Fig. 5.4 depicts the embedded relationship between the individual and social levels. Some factors that could exist on the social level are also depicted and include Home, Family, Work, School, Neighborhood, Religion, Culture, Race/Ethnicity, Socioeconomic Status, and Social Networks.

The home represents the most proximal social-level factor since it includes many elements, including a sleeping environment, social dynamics, access to other behaviors such as eating, socializing, working, relating to family members, etc. It is (often) the place where people generally sleep, which gives it a prominent place. Many previous studies have described ways in which elements of the home might impact sleep. Related to the home is the family. The family can play an important role in an individual's sleep. The family may represent the source or model for sleep-related beliefs, attitudes, and behaviors. The family may also represent a source for aspects of the individual such as health and even genetics. The family—which represents both the nuclear or extended family—plays many roles in an individual's sleep.

Another key factor at the social level is work or school. This is another complex factor that subsumes schedules, social circles, stresses, expectations, hierarchies, physical environments, logistics, and other factors. For those in school, school start times have been explored as key determinants of sleep [40–43] and modifying them has been shown to be helpful for promoting sleep. School-related stresses (in many forms) can impact sleep of young children and adolescents alike. For working adults, the workplace similarly can impact sleep—especially by dictating work demands, schedule demands, and sometimes even out-of-work activities (including evening activities). Problems at work can impact sleep and poor sleep can impact performance at work [37].

Aspects of the built environment are also relevant at this level. The built environment represents the buildings, streets, and other man-made elements of the environment. Ways in which these elements may impact sleep can be direct (for example via light or noise) or indirect (for example via crime and stress). The social environment is also relevant at this level. This includes an individual's social network of friends, acquaintances, and other people that may contribute to norming, behaviors, beliefs, and other individual-level factors. It can also represent aspects such as race/ethnicity and socioeconomics, which are also related to sleep at an individual and population level.

The model suggests that it is factors at the social level that are largely responsible for the factors at the individual level. In some cases, the social-level factors represent an explanation for the origin of some of the individual-level factors (e.g., predisposition for a physical or mental health condition). In other cases, individual-level factors are facilitated or impinged on by the social-level factors (e.g., work schedules). Alternatively, social-level factors may more subtly shape individual-level factors (e.g., beliefs, practices and attitudes). In some cases, a sleep intervention at the individual level will be inert unless social-level factors are considered (e.g., individuals working multiple jobs).

SOCIETAL LEVEL

Just as the individual is embedded within a social context, these factors, too, are embedded within an even broader societal context. Just as the social level describe the forces that converge to act upon the individual, the societal level represents the forces that impact the social context and, in turn, the individual. Fig. 5.5 adds the societal layer to the model, listing societal factors such as globalization, 24/7 Society, geography, public policy, technology and progress, racism and discrimination, economics, and the natural environment as factors that directly and indirectly affect sleep.

The social level represented constructs that exist outside of the individual but of which the individual is a part (with a key element that if the individual ceased to exist, those structures would still exist). Similarly, the societal level consists of constructs of which the social-level factors are a part, and would persist even if those factors would cease to exist. For example, globalization exists outside of any one workplace or organization, but arguably most workplaces and organizations participate in globalization in ways ranging from outsourcing to calling tech support in another country. Similar constructs that exist at a regional, national, and/or global level are included in this level.

Although individual-level factors are proximal and more direct causes of an individual's sleep experience, societal factors are also critically important. Although they may

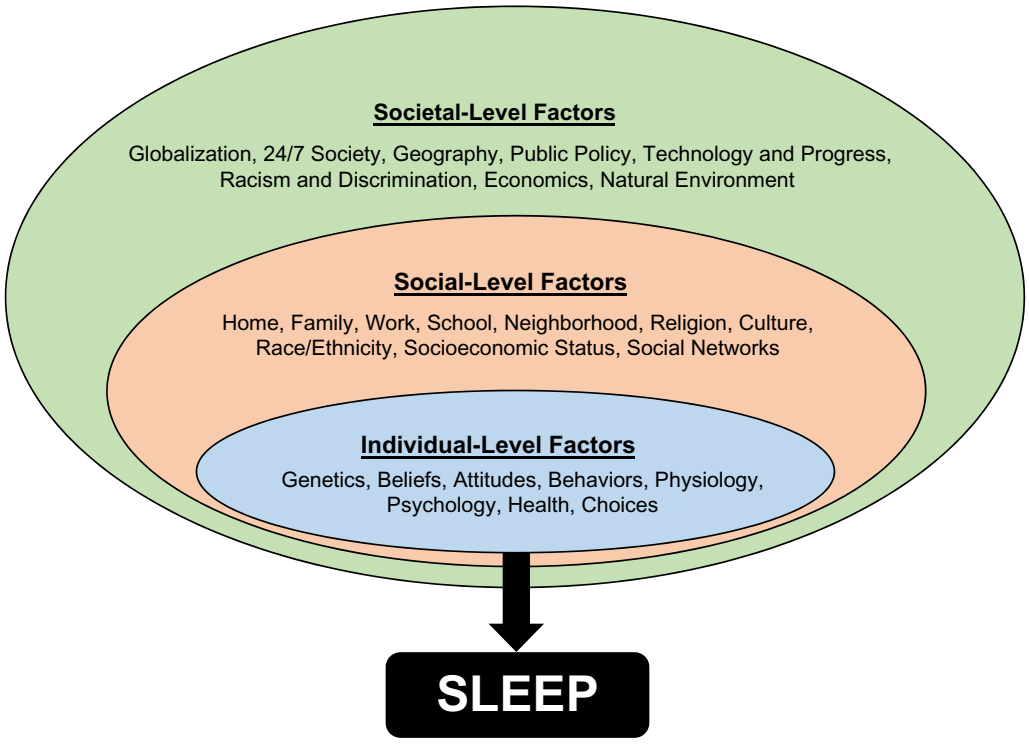

FIG. 5.5 Individual, social, and societal influences on sleep.

be less readily modifiable, conceptualizing an individual's sleep without considering the role of these factors omits important contextual information. For example, the increased drive toward globalization has interacted with the 24/7 society brought on by automation and the industrial revolution. This has led to products and services available at all hours of the day, and, consequently, the awake consumers taking advantage of this opportunity and the shiftworkers employed to meet these demands. Public policy and economics may also impact sleep, whether it be reflected in school start times or regulations about sleep disorders testing, or workplace rules, or light/noise ordinances, or other policies. Factors such as economic stress can impact an individual's sleep whether that stress is felt at the individual level [44], at the level of the neighborhood [45–47], or even at the national level [48, 49]. The physical environment and geography may dictate elements that impact sleep such as sunlight duration, weather patterns, disease risk, local culture, green space, pollution, traffic, or other aspects of the environment. Technology represents a particularly salient factor that indirectly influences sleep. There has been much discussion about the sleep-related effects of using technology in the bedroom [50], which has quickly become ubiquitous in our society.

Taken together, the combined social-ecological model of sleep, represented in Figs. 5.5 and 5.6, attempts to conceptualize the upstream influences on sleep as being primarily driven at the individual level (representing aspects of the individual as well as what the individual thinks/does). But the model recognizes that these individual-level factors exist in a social context and it is these social-level factors that may dictate many aspects of the individual-level factors. These social factors, though, exist in the context of societal factors that operate at a macro level, influencing communities, workplaces, schools, and families, which then subsequently influence individuals. In this way, a societal-level factor (e.g., development and adoption of mobile technology) influences social-level factors (e.g., workplace emails at all hours of the day), which subsequently influences individual behavior (e.g., sleeping with a smartphone by the bed).

COMBINING UPSTREAM INFLUENCES AND DOWNSTREAM CONSEQUENCES

The role of sleep as a mediator or moderator on aspects of health is still relatively unclear. Sleep could mediate or moderate the relationships between individual-level factors and adverse health outcomes. Namely, these relationships could

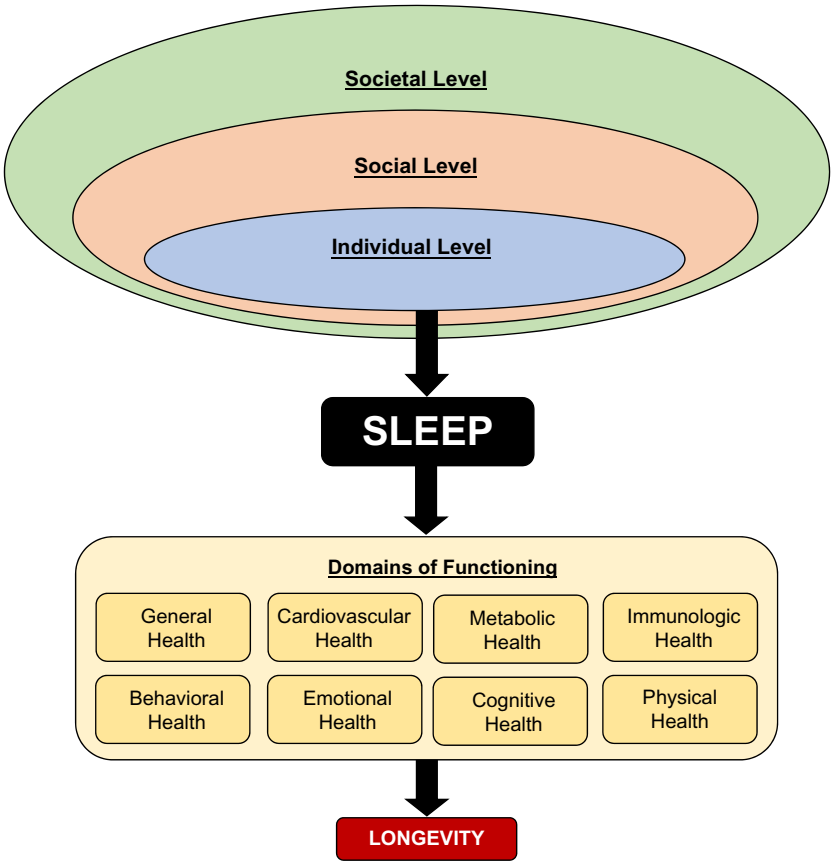

FIG. 5.6 Full social-ecological model of sleep and health.

be partly explained by the effects of the individual-level factors on sleep, which, in turn produces adverse outcomes (mediator), or process involved in sleep could change the strength of relationships between individual-level factors and adverse outcomes (moderator). Likely, these relationships are complex. Future research will need to better clarify this. For parsimony, figures only display the mediation relationship, though this is not the only possibility.

APPLICATIONS OF THE MODEL

The first version of this model for sleep health and mortality risk was originally proposed by Grandner et al. [2] and has since appeared in various forms in several other publications (e.g., [16, 51–53]). This model has been modified to fit various publications because the concepts underlying it are flexible. For example, the model could be used to develop interventions by examining modifiable targets that account for the social environmental context. The model can also be used to conceptualize the role of sleep in health, with sleep being more than just a set of physiologic processes.

This is somewhat more evident in the simplified version of the model presented in Fig. 5.7. This version highlights the core of what the model is describing—sleep exists at the intersection of upstream influences (individual, embedded within social, embedded within societal) and downstream influences that encompass the combination of health outcomes and functioning/performance. Although this version is simplified, the core elements remain, including the nested determinants and the explicit implication that health and functioning are inseparably overlapping as outcomes of sleep. Future studies could use this model to better understand the health context of factors related to sleep (such as health disparities, public policy, etc.), to better understand the role of upstream factors in sleep-related outcomes (such as sleep-related cardiometabolic risk), and to better develop and contextualize healthy sleep interventions that aim to improve downstream factors while addressing the contextualized upstream determinants.

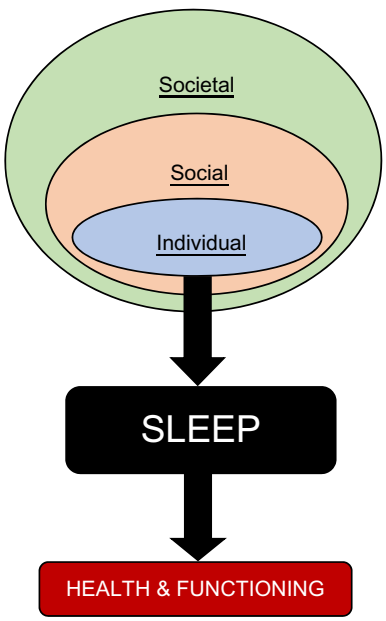

FIG. 5.7 Simplified social-ecological model of sleep health.

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