Chapter 21

Complexity, Systems Thinking, and Health Behavior Change

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LEARNING OBJECTIVES

After completing the chapter, the reader will be able to

• Describe the characteristics of complex systems as they relate to health behavior change.
• Discuss how traditional models of health behavior change fail to address complexity.
• Demonstrate the need for a paradigm shift in developing solutions for complex problems and explore how systems thinking can further this process.
• Identify leverage points to support health behavior change.
• Describe practices to facilitate the evaluation of behavior change interventions using a complex systems lens.

Introduction

Creating health behavior change in populations is neither simple nor complicated; rather, it is complex. That is, behaviors generally have many causal factors and countless interactions between them that feed back upon one another. These causal factors, or determinants, are a mix of individual-level variables such as age, gender, genetics, beliefs, and motivation, which in turn interact with environmental factors that arise in the home, school, workplace, community, and social networks and are shaped by sociocultural influences, economic conditions, and government policies. In populations (which should be considered complex), the laws that describe the behavior of the whole are qualitatively different from the laws that govern the behavior of the parts (Vicsek 2002).
Early psychological models of health behavior change focused attention on the individual and on simple, direct relationships between variables like awareness, attitudes, and behavior. Environmental approaches shifted the focus from the individual to the environment and to the notion that health behavior could be promoted through environmental enhancement and restructuring. This shift recognized that behavior change could be a complicated rather than simple process. Complicated problems require additional levels of expertise and coordination to respond to their broader scale, but do not contain the hallmarks of complexity. Stokols describes the further shift to social-ecological models as the recognition that both the individual and the environment are important and that the degree of an individual’s “fit” in the environment needs to be understood (Stokols 1996). In this approach individual behavior change is nested within broader social determinants, pushing our thinking toward the aforementioned hallmarks of complexity, such as feedback loops, interdependence between system components and nonlinearity. However, although our models have begun to consider and describe health behavior as complex, we have yet to fully embrace a systems approach to conducting research, designing interventions, or evaluating their results.

Most simple and many complicated problems are best solved using a reductionist approach to understanding the causes of the problem and then devising appropriate solutions. For relatively simple problems, we are able to work out all the important relationships involved and identify the best prospects to targeting in interventions. But if we accept that the systems relevant to health behavior change in populations are complex, then we must also accept that the reductionist paradigm is inadequate and that different approaches are required. Complex problems are harder to pin down. In a sense they are less “knowable” (Rittel and Webber 1973), and, as a result, focusing on defining the causes of the problem may not be as helpful as figuring out what works for whom and under what conditions (Robinson and Sirard 2005).

Complex initiatives or interventions pose many challenges to researchers, program planners, and evaluators because of the qualities that make them complex. They may involve multiple heterogeneous interventions, nonlinear dynamic relationships between variables like knowledge and action, and many interdependencies between the actors and organizations involved. Complex interventions in the real world are often not well controlled, and both the path and the outcome may be emergent properties of the intervention (Gamble 2008). Methods for evaluating complex interventions are starting to emerge as well as methods for conducting evaluation using a complexity lens.

This chapter applies a complex systems lens to the challenge of creating behavior change in populations. It is guided by the notion that refocusing our attention on solutions appropriate for complex problems will accelerate progress against the many complex public health problems of our time. The first part of the chapter discusses the unique features of complex problems, using examples that help to illustrate various dimensions of the complexity of health behavior change. The next section briefly reviews current models of behavior change and the degree to which they consider behavior as complex. We then explore new models and approaches that arise out of systems thinking and complex systems science. Lastly, we consider how systems thinking has been incorporated into program evaluation practices and offer some guidelines for practitioners wanting to approach program planning and evaluation through a systems lens.

**Complex Systems Characteristics**

The term system has been defined in numerous ways. A very simple definition is that a system...
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is a delineated part of the universe that is distinguished from the rest by an imaginary boundary (Bar-Yam 2004). Once the boundary is defined, the properties of the system, the universe, and the interactions or interrelationships of the system with its universe can be described. Meadows defines a system as “a set of things—people, cells, molecules, or whatever—interconnected in such a way that they produce their own pattern of behavior over time” (Meadows and Wright 2009).

In this chapter, two sample systems, water and an individual human, will be used to illustrate key concepts that differentiate simple, complicated, and complex systems. Although complex in some ways, water also exhibits some of the characteristics of simple or complicated systems. It is made up of identical (homogeneous) molecules that include one oxygen and two hydrogen atoms combined through a chemical bond (H₂O). Water molecules interact with each other mostly in a random (stochastic) way, and when they interact with their “universe,” or external environment, some of the characteristics or resulting behaviors are predictable (deterministic; e.g., water turns to steam at standard temperature and pressure), though not all of them (e.g., it forms varying snowflake patterns).

Individual people, in contrast, are highly complex systems. In addition to being 60%-70% water, the human body is made up of trillions of cells of many different types that perform lots of different functions. Together, these cells enable characteristic behaviors such as locomotion, digestion, and cognition, but across a population (or populations) variations in genes and environment give rise to huge variation in behavior. Time also makes human behavior difficult to understand because our past influences our future behavior.

Thus, systems can be simple, complicated, or complex, and the complexity within the systems of relevance to health behavior change can vary considerably. Bar-Yam (2004) defines a complex system as a system in which the function and behavior of the whole system cannot be deduced from the behavior of the individual parts. But the definitions of complex system or complex adaptive system vary considerably in the literature. Wallis (2008) suggests that no single, shared sense of meaning exists.

Theories and strategies for behavior change in individuals and populations have, in some cases, recognized some of the characteristics of complex systems such as nonlinearity, time-dependence, and heterogeneity, but they have mostly ignored important ideas like emergence, feedback, adaptation, and self-organization. These are still early days in the effort to improve our understanding of many of the characteristics that make behavior change in populations complex. Some data and modeling has been used to focus on feedback loops and self-organization, but much more effort is needed across a range of health behaviors. We also need new tools to help us measure, study, and intervene with variables that may affect system-level behavior, such as trust, social capital, resilience, and complexity. For the purposes of this chapter, a complex system will be taken as one that includes at least some of the characteristics listed above and in table 21.1. Many of the characteristics of water make it a relatively simple or complicated system, whereas individual people and populations are much more complex.

Heterogeneity

Heterogeneous systems are systems with a large number of structural variations. The system structure consists of all of the elements that make up the system as a whole, including the subsystems, actors, and interconnections between these elements. In homogeneous systems, the structural elements tend to be identical or indistinguishable, such as the H₂O molecules that make up a glass of water. In complex systems, the structural units are heterogeneous.
Heterogeneity is important in health behavior change interventions not only because the targets of change are heterogeneous, but also because the elements of the system involved in delivering the intervention are likely to be heterogeneous, and that heterogeneity affects outcomes. The heterogeneity occurs at various levels of scale within the system. In Canadian schools, for example, school-level tobacco control strategies and policies vary considerably. Factors such as policy intention, policy implementation, and number of students smoking on school property can all act as determinants of smoking behavior in students in grades 10 and 11. Student behavior is also diverse at the individual level, where variables such as students’ perceived level of connectedness to their school and the number of members of an individual’s family who smoke also determine smoking behavior (Sabiston et al. 2009).

Program interventions are also heterogeneous when implemented in the real world, and little is known about the nature or impact of this heterogeneity. Many interventions have a common foundation, such as tobacco cessation quit lines (see chapter 10), which are generally based on the principle of multisession proactive counseling, but delivery models vary considerably. In the case of quit lines, factors vary, such as the number of hours of operation, languages available, specific type of services offered, level of training of counselors, and level of funding (Cummins et al. 2007). The impact of
heterogeneity in intervention delivery parameters on the effectiveness of interventions is largely unexplored.

**Nonlinearity**

A *linear relationship* is one in which a change in variable A leads to a constant proportional change in variable B; if a small change in A leads to a small change in B, then a large change in A leads to a large change in B. In other words, a graph of B versus A can be represented by a straight line. A *nonlinear relationship* is one in which the effect is not proportional to the cause; even if a small change in A causes a small change in B, a large change in A might cause B to go up, or down, or even stay constant. In this scenario, the relationship between B and A cannot be represented by a straight line.

Some models of behavior change attempt to describe change with linear relationships between variables like knowledge, attitudes, and behavior (see “Focus on the Individual,” below) (Resnicow and Vaughan 2006). But evidence shows that many behavior changes, such as quitting smoking (West 2007), going on a diet (Ogden et al. 2009), or relapsing from abstinence (Hufford et al. 2003), are nonlinear functions of the variables that contribute to the behavior. In the case of smoking cessation, West and Sohal (2006) demonstrate that cessation is not linearly dependent on planning and that most successful quit attempts are unplanned and appear to be spontaneous. Similarly, individuals who have been successful in losing a large amount of weight and keeping it off for an extended period of time often report that a “trigger” prompted them to initiate weight loss (Ogden et al. 2009). **Triggers** are often described as vague decisions to “just do it” (Klem et al. 1997). Triggers may also be associated with specific life events such as relationship problems, a birthday, or illness. Ogden and co-workers (2009) also observed that the same trigger may lead to different outcomes for different individuals; for example, relationship problems were associated with both weight loss and weight gain. If triggers can be powerful at the level of the individual, they will also have significant impact on the behavior of populations.

Resnicow and Vaughan suggest that the many nonlinear relationships that contribute to behavior change make it “chaotic” and difficult to predict; as a result, they argue, linear models of behavior change are “both conceptually inappropriate and statistically futile” (Resnicow and Vaughan 2006). Instead, they suggest that we need a new theory for behavior change that recognizes these nonlinearities and leads to the development of more appropriate interventions. Some authors have called for more research to understand the importance of nonlinearities (Brug 2006), whereas others have begun to explore the role of nonlinearities in individual responses to treatment (Hayes et al. 2007). Green described a range of nonlinearities in the dynamic response to health education programs. These nonlinearities, including “delay of impact,” “decay of impact,” and “borrowing from the future,” make it difficult to design interventions and the protocols for measurement and evaluation of their impact (Green 1977).

**Unpredictability**

A *stochastic process* is one in which an element of randomness leads to a degree of uncertainty about the outcome. In contrast, a *deterministic process* is one in which the same result always occurs for a given set of circumstances. Deterministic systems behave in a predictable way, whereas stochastic systems are less predictable. Stochastic systems in some instances are considered **probabilistic**; that is, the behavior of the system cannot be predicted exactly, but the probability of certain behaviors is known.

For water at the level of individual molecules, the movement of any given molecule is stochastic or random, but the behavior of a group of \( \text{H}_2\text{O} \) molecules at sea level is deterministic—it...
will always turn from liquid to gas when the temperature hits 100°C. In individual people, the development of a particular disease usually depends on both predictable and unpredictable factors. For example, smoking increases the risk of developing lung cancer, but not everyone who smokes gets the disease. Likewise, obesity increases the risk of developing diabetes, but not all obese people become diabetic. Disease development has both deterministic and stochastic elements (Levy et al. 2010; Plevritis et al. 2006).

The probabilistic or stochastic nature of health behavior change in response to some stimuli or interventions is well recognized. Also well known is that the degree of certainty in most predictive models of behavior change is rather low. In general, it has been considered acceptable to publish models that account for only 10% to 20% of the variance in behavior. Models accounting for more than 50% are rare (Baranowski et al. 1999; Roter et al. 1998). So, although few would argue that behavior change is deterministic, a debate is emerging regarding the interpretation of the “unpredictable” portion of behavior and what to do about it. Baranowski argues that we are just not doing a good enough job of pinning down all the causal factors and need to work harder, whereas Resnicow and colleagues suggest that we need new ways of thinking about behavior change—that is, we need new models and tools that accept the unpredictability of behavior change (Baranowski 2006; Resnicow and Page 2008; Resnicow and Vaughan 2006).

Dynamics

In dynamic systems, change in the state of the system happens over time, and the past has an impact on the future. Complex systems are often time dependent and have properties like growth and death, which are dynamic processes. In static systems, nothing changes over time; time is not an important variable.

Consider water in a glass or a pond. Although at the microscopic level, the water molecules are moving at all times, their motion is completely random, and the behavior of the water at the macroscopic level essentially does not change over time. This is a relatively static system. When water flows, it is more dynamic. Glass and McAtee use an analogy of flowing water to describe the health behavior of an individual; an individual’s “sphere of health-related behavior and action moves through time from infancy to old age,” and the trajectory of the sphere is influenced by opportunities and constraints (to the flow) posed by external environments and the expression of biological systems (Glass and McAtee 2006).

The dynamic nature of behavior change in populations was well described by Rogers in his work on diffusion of innovation (see chapter 7). Rogers described the dynamics of diffusion as starting slowly among innovators and early adopters, then accelerating as the middle majority adopt the innovation, and finally slowing down when only the laggards remain (Rogers 2003). Each adopter’s willingness and ability to adopt an innovation depends on a variety of factors including the person’s awareness, interest, evaluation, and trial of the innovation.

Green points out that the dynamic nature of a population’s response to health education interventions makes it difficult to measure their outcomes and determine their impact. In his example of borrowing from the future, the dynamic response to a trigger of health information may in the short term look quite positive. Mass media campaigns have been shown, for example, to cause an increase in the number of people recruited into screening or family planning clinics. But in the long term, these interventions may not always increase the number of patients recruited overall; they just shorten the time interval over which patients present themselves to the clinic (which could have the unintended consequence of making the flow of new patients also highly variable) (Green
A better understanding of dynamics could improve both the design and evaluation of interventions.

**Interdependency**

Interdependence of the elements in a complex system refers to the “level of connectedness” of the parts of the system. Interdependence is a characteristic that often makes it difficult to predict the impact of changing one part of the system. If the elements of the system are independent or simply connected and not interdependent, then removing a part of the system will have little or no effect on the part removed or the remaining parts (Bar-Yam 2004). Consider, for example, the removal of a drop of water from a glass of water; the properties of the drop and of the rest of the water in the glass are not changed very much.

If, however, the elements of a system are interdependent, then pushing on or removing one part could have a strong effect in another area of the system. Consider again human form and function. Removal of some parts of the human body will have little or no effect on other functions (e.g., hair, a fingernail, or a toe); removal of other parts will have an effect on some functions and not others (e.g., removal of a leg will affect locomotion but not digestion); and some parts of the human system are so interdependent that their removal will affect all other subsystems (e.g., the heart or the brain).

Biological science struggles with the complexity of intact organisms and the highly interconnected nature of biological control mechanisms (Goh et al. 2007). The usual paradigm in biological science is reductionist, and it requires controlling as many variables as possible to be able to see where there are important causal relationships. Reductionist approaches in basic science include the creation of “knock-out” and “transgenic” mice, in which the expression of a particular gene is prevented or added. Although the motivation behind these methods is to isolate the impact or function of a single gene, the results are often surprising, with single genes affecting multiple systems and multiple genes being responsible for a single phenotype or characteristic biological response (Goh et al. 2007; Kirchner et al. 2010).

The Foresight system map for obesity illustrate complexity on a broader, social scale and suggests that many elements in the environment that influence behavior are interconnected (figure 21.1) (Finegood et al. 2010; Vandenbroeck et al. 2007). Food consumption depends on food production, food consumption influences physiology, and social psychology affects individual psychology (Finegood et al. 2010). Although the Foresight map nicely illustrates the importance of interconnections, little has been done to assess the actual levels of interdependence in the obesity system. In the case of tobacco control (see chapter 10), interdependencies were explored through the building of a causal map and model (Best et al. 2007). Using system dynamics methods, researchers explored the importance of various factors, such as public opinion, research, knowledge dissemination, and government intervention, for the prevalence of smokers from 1965 through to 2020. Interestingly, public opinion was found to have a substantial effect on the prevalence of smoking, but it also had the unintended consequence of decreasing the amount of translational research undertaken. This interdependency was a function of the increased demand by the public for more research, but what was desired was a shift in the type of research away from knowledge translation and toward more basic science (the kind of research the general public thinks of as research).

Interdependence makes it difficult to ascertain the direct cause and effect relationships that make a problem complex, and it suggests that solutions need to be comprehensive. In a system with many interdependencies (such as the obesity system described by the Foresight map), isolated action in one part of the system
British Columbia stimulated cooperation by creating a competition for project funds among all ministries of the government (Geneau et al. 2009). The competition resulted in a large number of cooperative projects, which included multiple ministries and created a novel approach to influencing health outcomes. The relationship between competition and cooperation is sufficiently powerful that a key recommendation in Bar-Yam’s suggestions for health care reform is to “empower workgroup competition”; if established at the right level, workgroup competition will lead to cooperation among the actors who need to work together to create change (Bar-Yam et al. 2013).

Feedback

The presence of feedback loops is a key feature of complex systems, and they are of two major types. Feedback loops create a closed chain of causal connection (e.g., an increase in A leads to an increase in B, but the increase in B in turn leads to a decrease in A). This is called a nega-
tive, or balancing feedback loop because it tends to cause stability in the system. For example, the National Weight Control Registry project established by Hill and Wing has collected data on what characteristics and factors contribute to long-term weight loss maintenance. One of the key findings is that people who successfully maintain a long-term weight loss weigh themselves frequently (Butryn et al. 2007), possibly because when an individual observes a small increase in his weight, he adjusts food intake and physical activity behaviors to induce weight loss. An increase in weight (variable A) leads to a decrease in food intake (variable B), which in turn reduces weight back to the desired stable level.

Alternatively, positive, or reinforcing feedback loops tend to amplify or enhance systems change. A reinforcing loop can encourage growth in a system, where an increase in A leads to an increase in B, and the increase in B then tends to cause a further increase in A. An example of a reinforcing loop from the Foresight map is that the “demand for convenience” leads to increased “convenience of food offerings,” which leads to “deskilling” (i.e., loss of food preparation and cooking skills), which, in turn, increases the “demand for convenience” (Vandenbroeck et al. 2007). Reinforcing loops can be characterized as either vicious or virtuous for the overall well-being of the system, depending on which direction the system is pushed. The relative dominance of balancing and reinforcing loops will determine the overall stability of the system and whether vicious or virtuous reinforcing feedback loops will take over and push the system in a particular direction. These feedback loops are a hallmark of complexity; simple or complicated systems tend to have few feedback loops.

Feedback loops abound in the Foresight obesity system map (Vandenbroeck et al. 2007). In an analysis of this map, we identified more than 100 feedback loops with as few as two and up to as many as 17 variables in a given loop (Finegood et al. 2010). A preliminary analysis of the types of loops suggests that reinforcing loops greatly outnumber balancing loops (data not shown). For example, stress and perceived lack of time have positive influences on each other (perceived lack of time increases stress levels, and increased levels of stress cause a further increase in perceived lack of time; this is an example of a vicious cycle). In contrast, walkability of neighborhoods and the dominance of motorized transport have reciprocal negative influences on each other (as the dominance of motorized transport increases, the walkability of neighborhoods decreases, leading to further need for and dominance of motorized transport). The high number of reinforcing feedback loops in the Foresight map may help to explain the emergence of obesity as a prevalent condition in most populations and may also help explain its apparent resistance to our current levels of intervention.

Adaptation and Self-Organization

Adaptation and self-organization refer to the ability of a system to arrange itself, to create new structures, to learn by responding to the environment in which it is situated, and to diversify. Self-organization occurs through the interactions of the elements of the system rather than through some central authority or control mechanism.

Water changes in response to its environment by becoming a solid or a vapor. The relative simplicity of water as a system means that these changes are fairly deterministic, and their impact on the environment is fairly predictable. The subsystems that make up individual human beings, in contrast, are very complex and afford a range of levels of adaptability and self-organization. Stem cells are a good example of a highly adaptive, self-organized biological subsystem without central control (Halley et al. 2009). Populations are also highly adaptable, self-organized systems that respond to changes
In their environment and also have significant impact on the shape of the context in which they live. Society is still rooted in the notion of central control (e.g., governments), and the institutions and organizations we have built struggle to adapt and respond to longer-term changes in the environment (Bar-Yam 2002).

In population-level interventions, the notions of adaptation and self-organization of the larger system are often discouraged or ignored in an effort to maintain fidelity (Dumas et al. 2001). As a result, information about how the defined intervention is adapted in real-world settings and how adaptation affects the outcomes is usually not available (Green 2006). Hawe and colleagues argue that we need to redefine what standardization means in controlled trials (Hawe, Shiell, and Riley 2004). In complex interventions, the function and process of the intervention should be standardized rather than the components themselves. These authors suggest that rather than having design standardized by form (e.g., all sites distribute the same information kit to patients), they should be standardized by function (e.g., all sites devise ways to distribute information tailored to local literacy, language, culture, and learning styles). This approach promotes and supports self-organization and adaptation rather than trying to control it.

Cohen and colleagues looked at the trade-offs between fidelity and flexibility in a real-time, cross-case comparison of 10 interventions designed to improve health promotion in primary care practices in practice-based research networks (Cohen et al. 2008). They found that all of the interventions required changes as they were integrated into practice. They concluded that change is common and that dissemination and implementation will improve when our approach shifts to focus on quality improvement. The only one of the 10 interventions in their study that reported requiring no changes when integrated into practice was the one that was initially and intentionally designed to support adaptation.

**Rigidity** inhibits adaptation and self-organization, and this compromises resilience and the long-term health and survival of a system. Bar-Yam highlights the importance of building systems that support and promote adaptation with his recommendation to “empower workgroup competition” as part of health care reform (Bar-Yam et al. 2013). With a systems approach, our natural tendency to want to control adaptation gives way to the need for structures and processes that support self-organization at the level in which people can be empowered to make real change. We are only at the very beginning of creating the structures and processes necessary to support adaptation and self-organization among the actors working to improve public health.

**Emergence**

As with the term complex adaptive system, no consensus exists on the definition of emergence. Emergent behavior is collective behavior that cannot be simply inferred from the behavior of individual system components. Although emergence is collective behavior that is contained in the behavior of the parts, the parts must be studied within the context of the whole. Bar-Yam suggests that what is important about emergence is neither the parts nor the whole but rather the relationship between the details of the system and the larger view. In trying to explain the property of emergence, he uses the saying “You can’t see the forest for the trees.” If you focus only on the details of the individual components (e.g., the trees, the soil, or the animals), you risk missing the bigger picture. If you focus only on the forest, you run the risk of missing the aspects of trees that give rise to the behavior of the forest, and so forth (Bar-Yam 2004). Being able to zoom in and out is necessary to understanding emergence.
Consider again the Foresight obesity system map (Vandenbroeck et al. 2007). That map was built through the engagement of a wide range of stakeholders. The overriding message of the map is that the problem is complex and involves many different factors associated with both the individual and her environment. The specific variables that make up the map and the relative importance of different clusters of variables, such as those influencing food production and physical activity environments, are not really discernible. However, when we “zoom out” on the map, as we did to create a “reduced” map, new details emerge (Finegood et al. 2010). The reduced map, for example, suggests that the stakeholders involved perceived a significant effect of food production on food consumption. This connection appears to be substantial, though it may reflect the biases of the participants in the processes. It may be that some of the actors involved in these two clusters (e.g., people who work in the food industry) were under-represented.

Little has been written about the notion of emergence as it relates to health behavior change. We have argued that obesity is an emergent property of the system depicted in the Foresight map (Finegood 2011). Wolitski has used the term emergence to describe the rise of barebacking (intentional unprotected anal sex) among gay and bisexual men in the United States (Wolitski 2005). Individually, causal factors such as improvements in human immunodeficiency (HIV) treatment, knowledge of a partners HIV status and the relative risks of specific acts the rise of Internet use, substance use, and changes in HIV prevention programs do not explain the rise in barebacking, but together, they give rise to the phenomenon. In analyzing if schools that claim to be “health-promoting” function as complex adaptive systems, Keshavarz and colleagues suggest that the overall collective behavior and health-promoting nature of the school are the emergent products of the interplay of many different factors, such as rules, interactions, information, values context, and time (Keshavarz et al. 2010).

Clearly, new methods and tools are needed if we are going to make progress in understanding and using the characteristic of emergence. Wheatley and Frieze argue that emergence can be used to scale up social innovations by deliberately influencing the process as it moves through its life cycle (Wheatley and Frieze 2006). The life cycle of emergence begins with networks of people who share a common cause around a particular problem or social change. When support and resources are provided for these networks to act as cooperative teams and connect with other networks, they can grow into intentional communities. These communities are likely smaller subsets of the people involved in individual networks; they form among the individuals who are committed not only to their own agendas but also to serving the needs of others. Ultimately, from healthy and vibrant communities emerge systems of influence where change may be rapid and a shift in the dominance of some feedback loops may occur. By connecting and supporting social innovation occurring on a small scale in disparate networks, more intentional communities can be formed and are the nucleus for change on a larger scale.

**Systems Thinking and Models of Behavior Change**

Theories of behavior change have evolved from giving rise to simple or complicated individual-level or environmental-level interventions to including more and more aspects of complexity. We now recognize the need for more complex system models, which examine key elements of complexity with respect to psychological, biological, social, cultural, and built environment factors (Foster-Fishman and Behrens 2007). Some of the methodologies of systems science are helping to integrate these details to
enhance understanding of the behavior of whole systems.

**Focus on the Individual**

Models of health behavior change that form the basis for most past and current interventions have evolved considerably over the past 30 years. The earliest theories of health behavior change were focused on the individual. Change would occur if an individual’s knowledge, attitudes, and beliefs were modified, and active interventions required voluntary and sustained effort to achieve success (Stokols 1996). These psychological models have been broadly classified as continuum (e.g., *Theory of Planned Behavior*, *Health Belief Model*) and stage models of behavior change (e.g., *Trans-theoretical Model*, *Precaution Adoption Process Model*). In continuum models, the general approach is to identify variables that influence action, such as knowledge, attitudes, perceptions of risk, and perceptions of benefit, and to combine them into a predictive equation. The value generated by the equation for a particular individual indicates a given probability that the person will act, which places each individual along an ordered and predictable continuum of likelihood to act. Weinstein and colleagues argue that because each theory has only a single prediction equation, the way in which variables combine to influence action is expected to be the same for everyone (Weinstein et al. 1998). As such, behavior in these models is considered deterministic. Baranowski suggests they should be labeled probabilistic, because the equation usually has an error term, unless “we could account for 100% of the variance” (Baranowski 2006). The level of variance provides some index of the degree to which the model is deterministic. In addition, the fact that most models are linear combinations of independent variables also contributes to their being considered simple or somewhat complicated models.

Stage models of behavior change attempt to deal with some of the heterogeneity of individuals by suggesting that people pass through stages of change and can be classified into a limited number of categories based upon their phase during the change process. In stage models, such as the transtheoretical model, the members of a given stage have attributes that define that stage. For example, smokers who had no intention to quit within the next six months were classified as being in *precontemplation*, those who were intending to quit but had not tried for at least 24 hours in the past year were considered to be in *contemplation*, and those who intended to quit and had tried for more than 24 hours in the past year were considered to be in *preparation* (DiClemente et al. 1991). Although assignment to a particular stage does not define the population in that stage as entirely homogeneous, it attempts to account for heterogeneity in a population by suggesting that there are smaller differences among people in the same stage as compared to relatively large differences between people in different stages (Weinstein et al. 1998). The ordered stages also help to define common barriers to change facing people in each stage, such as differences in *self-efficacy* (DiClemente et al. 1991; Marshall and Biddle 2001). Although the proponents of these models acknowledge that people do not necessarily move through these stages in a linear fashion, this model is still an attempt to describe behavior change as deterministic and rational (West 2005). The result is a continued belief that behavior change is predictable if we can simply identify the most important variables and classify individuals in relatively homogeneous groups.

**Focus on the Environment**

Another class of models on which interventions have been based are models in which the quality of people’s physical and social environments is the focus of attention. Here the inter-
vention approach is to improve environmental hygiene or safety and to strengthen social supports for health. Stokols describes these as **passive interventions**, insofar as enhancing and restructuring environments does not require the individuals exposed in them to *do* anything (Stokols 1996). These models are based in theoretical and research approaches such as industrial hygiene, injury prevention, occupational epidemiology, facilities design and management, and environmental health science.

But, as Stokols points out, these models pay little attention to the sociodemographic characteristics of the people occupying particular places and settings (Stokols 1996). As such, these models neglect the individual and group differences in people’s responses to their environments (i.e., the *interaction* individuals have with their environments). Clearly, the lack of consideration of interdependencies and feedback loops makes these relatively simple models as well. If they take into account multiple dimensions of the environment, they might be considered complicated, but probably not complex.

**Focus on Complexity**

The social-ecological approach recognizes that both individuals and their environments are important determinants of behavior change (Louns bury and Mitchell 2009). **Social Ecological Models** accept that individuals have a variety of personal attributes (genetic, psychological, behavioral) that interact in a dynamic fashion with attributes of the environment (physical, social, cultural). Stokols suggests that the social-ecological approach requires a focus on the degree of fit between individuals’ needs and the resources available to them (Stokols 1996). This is similar to Bar-Yam’s notion that, in complex systems, individuals matter and it is important to match their capacity to the complexity of their task (Bar-Yam 2004; Finegood 2011).

Glass and McAtee push social-ecological models further into the realm of complexity by suggesting that we need new metaphors and models to integrate the many variables that affect health and disease. They introduce a general approach that attempts to include both the individual, with his context, and his interactions over his life course. Their framework includes a nested hierarchy of individual-level factors from genes, to cells, to organs, to social networks, to the global environment. They suggest that we learn to apply the metaphor of an individual in her sphere of environments flowing through life with various bumps and valleys along the way (Glass and McAtee 2006). Although the figure depicting the model does not convey the importance of feedback loops, they acknowledge that feedback and interaction must be important components of new theories of behavior change.

In the example of obesity, the International Obesity Task Force introduced a **causal web**, which positioned the individual or the population level of energy intake and energy expenditure to the right of a series of environmental influences ordered in proximity to the individual, including influences in work, school, and home environments and influences at community or locality, national, and international levels (Kumanyika 2001). Introduced more than 10 years ago, this model helped to shift the paradigm in obesity research from a focus on the individual to a focus on the many-layered environment. The Foresight map, which was introduced more recently, incorporates many of the same concepts as the causal web (e.g., the importance of physical activity, food, and social environments), but it illustrates them in such a way that the connections dominate the image, not the individual variables or sectors of the environment that influence food and physical activity behavior (Vandenbroeck et al. 2007). The causal web is a good illustration of obesity as complicated, whereas the Foresight map illustrates the problem as complex.

Resnicow and colleagues have called for new models that recognize the “quantum” and
“chaotic” nature of individual behavior change (Resnicow and Page 2008; Resnicow and Vaughan 2006). They suggest that enduring behavior change is unplanned. West and Sohal also suggest that we need to account for behavior changes that “just arrive” and are associated with motivational statements like “I just decided to do it” (West 2007; West and Sohal 2006). The push to accept these characteristics of complexity in models of behavior change has provoked some to argue that we need to improve the quality of research (Baranowski 2006) and that the implications of considering complexity are limited (Brug 2006). West argues that we need to recognize the artificial nature of staging people’s intentions and accept the fact that although decision making has a rational component, it also depends on reward and punishment, habit, and processes that operate outside of conscious awareness (West 2005). Although social-ecological models were the first to embrace some aspects of complexity, these quantum, or chaotic models push further into the realm of complex adaptive systems. Much more work will need to be done to understand and apply systems thinking as a basis for interventions to improve health behavior in populations.

**Computational Approaches**

In the current era, social-ecological models are evolving from their origin as conceptual models into computational, mathematical, and simulation models. The growth in computing capacity over the past few decades is making it easier to apply modeling methods to social issues like education, psychology, and health (Hawe et al. 2009). **Systems science** includes a variety of computational approaches such as system dynamics and micro-simulation as well as agent-based and multilevel modeling (Levy et al. 2010). Each method has particular advantages and disadvantages and should be used for different kinds of questions and under different circumstances, depending on the purpose of the model and the type of data available to inform model building. More work is called for in this intersection between systems science and public health (Leischow and Milstein 2006; Mabry et al. 2008).

Although a detailed description of these methods is beyond the scope of this chapter, we use the specific case of obesity to illustrate the potential for computational approaches to understanding health behavior in populations. **System dynamics** and **microsimulation modeling** have been used extensively to project into the future the prevalence of obesity in specific populations and to consider the impact of interventions on prevalence rates and projected costs (Levy et al. 2010; McPherson et al. 2007). Interventions are usually tested in a general way (e.g., by reducing caloric imbalance) rather than by modeling a specific intervention (e.g., bariatric surgery, a “walking school bus”), but these models provide important insights about the dynamics of change. Homer and colleagues demonstrated that even if caloric imbalance returned to 1970 levels in everyone, it would take many years to reduce the prevalence of obesity, and only targeting children would have a very small impact on the prevalence of adult obesity (Homer et al. 2006). This type of modeling underpins the Accessing Cost Effectiveness work on obesity (ACE Obesity) and other ACE projects, in which more specific comparisons were made (Ananthapavan et al. 2010; Carter et al. 2009; Vos et al. 2005; Vos et al. 2010).

**Network analysis** and **network simulation** have also been used to explore the importance of social interactions in the development of obesity. Christakis and Fowler (2007) used data from the Framingham study to build a model of the social networks of friends and to explore the development of obesity. Their analysis demonstrated that individuals with obese friends had a higher risk of subsequently developing obesity. Bahr and colleagues (2009) used network simulations to examine weight loss interventions and the importance of social net-
works. Hammond (2008) has advocated for agent-based modeling as a strategy to study obesity. He suggests that it would permit modeling of multiple mechanisms simultaneously, across several levels of scale, with inclusion of important sources of diversity. One challenge with these types of models will be the lack of sufficient data on individual agent decision making (Johnson-Askew et al. 2009).

The Institute of Medicine (IOM) recently called for the use of systems perspectives and methodologies in defining the problem of obesity so that more effective decisions can be made in prevention and population intervention. The IOM notes that “the demand for results-oriented research is gradually forcing a shift beyond linear models to models that also address the dynamic, multilevel complexity of real-world contexts” and that a systems approach can help to highlight the broader context, to consider interactions among levels and the dynamic shifts that occur over time (Kumanyika et al. 2010).

A Paradigm Shift to Solutions Fit for Complex Problems

Common responses to complex social problems tend toward frustration, despair, disillusionment, retreat, and belief that the problem is beyond hope (Bar-Yam 2004; Plsek and Greenhalgh 2001). We want to look for someone to blame, or we focus on simple solutions. More than 35 years ago, Rittel and Webber (1973) suggested that we cannot continue to tackle complex problems by assuming that through analyzing the component systems we will be able to identify root causes and then fix the problem. They point out that the most intractable problem is that of defining and locating the problem in the first place (i.e., finding where in complex causal networks the trouble really lies). Characteristics like heterogeneity, interdependence, feedback, and adaptation make many social problems “wicked” problems, and wicked problems are challenging because they have no definitive formulation and no stopping rules, and there is no ultimate test of a solution. As Sterman (2006) suggests, we lack meaningful systems thinking capabilities.

To truly embrace the notion of complexity and adopt a solution-oriented approach, our mental models will have to help us shed dependence on causality and shift to complexity as a way of knowing. This shift will require new metaphors, or a paradigm shift, in how we think about and value different types of research and evaluation (Glasgow 2008). Rather than searching for identification of what causes problems, Robinson and Sirard argue, we need to look for what causes the solutions. Solution-oriented science can still be rigorous science with appropriate hypotheses that can be tested. They suggest that hypotheses need to shift from a “past” orientation to a “future” orientation, which focuses on understanding what works and what does not work to solve problems. Robinson and Sirard (2005) suggest that the solution-oriented research paradigm encourages research with more immediate relevance to human health and a shortened cycle of discovery from the laboratory to the patient and the population.

Hawe and colleagues are also questioning the dominant paradigm for how randomized controlled trial design is being applied to community interventions (Hawe, Shiell, and Riley 2004; Hawe, Shiell, Riley, and Gold 2004). The current paradigm has “control” placed over the intervention (i.e., the intervention needs to be the same in different places), and this is thought to be of paramount importance, but it may also be why large-scale trials have mostly had weak effects. Hawe and colleagues point out that shifting the notion of what is standardized, from form to function, would have a dramatic impact on the questions that are addressed by the research and evaluation team (Hawe, Shiell, and Riley 2004). As noted above, this would be a way of refocusing the objective of the measurement process to support adaptation, without compromising the
Places to Intervene

In the late 1990s, Donella Meadows described 12 leverage points, or places to intervene, in a complex system (Meadows 1999; Meadows and Wright 2009). This list was developed out of her desire to move toward solutions and her frustration that, in complex systems, the leverage points people tend to pick are usually wrong. She argued that true leverage points are often counterintuitive and therefore difficult to locate. Her generic list of ordered leverage points goes from the lowest level, consisting of things that are easy to change and tend to have a small effect on the system as a whole (e.g., elements of the system, such as numbers of physicians or health information), to the things that are higher up in the system and are much more difficult to change but can have a very large effect on the system (e.g., the paradigm under which the system operates and system goals). It provides a generic framework for all complex systems.

We sought to use Meadows’s ideas in the development of a framework that could serve as a tool in research and evaluation. Our initial effort was to use her 12 leverage points to sort recommendations to address childhood obesity and chronic disease prevention that were made by the participants attending a conference on childhood obesity. This experience suggested that 12 levels were too many to provide a useful and reliable framework (Malhi 2009). Through an iterative process, we settled on a five-level framework that could be used reliably to sort action statements for change in complex systems. The five levels correspond roughly to broader groups of Meadows’s 12 levels mentioned above: (1) paradigm, (2) goals, (3) system structure, (4) feedback loops and delays, and (5) structural elements (Malhi et al. 2009).

Since the development of the Intervention Level Framework in 2009, we have successfully applied it in several different ways. In one project we used the framework to examine a series of papers prepared for a conference on food systems and public health (Malhi et al. 2009; Story et al. 2009). In this exercise, content was first sorted according to the four conference themes: food systems that are healthful, green, fair, and affordable. Then the content was sorted again according to the framework. By using the framework to order this content, places where advocates for food systems agree and disagree became quickly apparent. For example, advocates of healthful and green food systems would agree on many of the structural elements needed, including reducing the use of pesticides and implementing other practices that are ecologically sound. In contrast, the advocates of green and affordable food systems conflict at the highest levels of intervention (e.g., the paradigm under which the system operates and the goals that derive from the paradigm). Specifically, in a green food system, prices would reflect the costs of toxic exposure, environmental cleanup, and depletion of natural resources, including fuel to transport the food long distances, yet an affordable food system would structure the price of healthful food so that it is...
affordable to the lowest income groups regardless of the environmental costs. By putting advocated solutions into a systems framework, new insights on characteristics, such as interdependence, and identification of gaps in feedback will support the development of novel system-oriented solutions.

The Intervention Level Framework is also being applied to sort recommendations to address childhood obesity, to sort qualitative data from families and clinical professionals on the barriers to and supports for weight loss, and to examine perspectives of multiple system actors on the prevention and management of obesity (Johnston et al. 2010; Matteson et al. 2010). Given the general nature of this framework, we anticipate that it will have many other applications, including program planning and evaluation of complex interventions.

Making Things Work

Another leading systems thinker has also forwarded the agenda of devising solutions based on some fundamental principles that arise out of complex systems. Yaneer Bar-Yam describes his experience solving complex problems in health care, education, the military, international development, and ethnic violence in his book Making Things Work (Bar-Yam 2004). Although Bar-Yam does not codify or provide a taxonomy of solutions, we distilled a simple descriptive set of actions from his summaries of what has worked based on his experience (Finegood 2006, 2011).

An important concept put forward by Bar-Yam is one that may seem counterintuitive; in a complex system individuals do matter. In particular, the individual’s capacity to act and the complexity of his task need to be matched. If the capacity of an individual is lower than the complexity of the task, the individual will fail, but if the capacity of the individual exceeds the complexity of the task, the individual is more likely to succeed (Bar-Yam 2002). This is similar to the notion of “fit” as described by Stokols and developed by Caplan as person-environment-fit theory (Caplan 1987; Stokols 1996).

Also, remember that individuals who are the target of a behavior change intervention (e.g., overweight and obese individuals) are not the only ones who matter. There are individual actors all over the systems relevant to health behavior change in sectors as diverse as government, academia, and the private sector—each playing a role in determining system outcomes. The individual battling an obesogenic environment and the CEO of a food company who needs to meet the demands of shareholders, consumers, and the public are both important players in the social system that produces obesity (Finegood et al. 2010; Yach 2008). All of these individuals matter, and their relationships to others they need to work with to solve problems also matter. Cross-sector and cross-disciplinary boundaries are common barriers in complex systems and represent points where leverage for change may be found.

Given the complexity of most behavior change problems and the broad and distributed nature of the actors involved (see figure 21.1), no particular hierarchy exists that controls activity across the system. Without a clear hierarchy or singular causative agent for a problem, a command-and-control approach to problem solving and innovation will not work (Bar-Yam 2004). To solve complex problems, it makes sense to distribute the authority to make decisions and support action in the various parts of the actor network that create the different sub-systems (Greenhalgh et al. 2009). However, the decision making must be distributed to actors with the capacity to act. This is the notion driving Bar-Yam’s recommendation to empower work-group competition as a means to address health care reform in the United States (Bar-Yam et al. 2013). In Canada, recent efforts to distribute action and authority across the “whole of government” have led to innovative efforts to address obesity and physical inactivity (Geneau
et al. 2009). Many other cooperative efforts are needed both within and between sectors to address a variety of pressing problems (Yach 2008).

In summary, the Intervention Level Framework developed from the work of Meadows, and the “solutions to complex problems” distilled from the experience of Bar-Yam are helpful tools to guide the application of systems thinking to real-world health behavior change in populations.

Evaluation through a Complex Systems Lens

If the systems underlying health behaviors are complex, then systems thinking must be central to how we intervene in those systems, whether the intervention is in policies, programs, or funding mechanisms. Increasing evidence suggests that interventions must be complex and occur at multiple levels to be effective (Kumanyika et al. 2010). The increasing complexity of interventions has implications for the methods used to evaluate interventions and demands adaptation on the part of the evaluator (Victora et al. 2004). In this section, we briefly review some of the ways in which the evaluation field has incorporated systems thinking to better meet the needs of decision-makers for program and policy assessment. Although this section focuses mainly on evaluation, it also highlights how these concepts can be incorporated into program planning, which will in turn affect evaluative practice.

Complex initiatives (also called horizontal initiatives or system change initiatives) pose many challenges to evaluators because they have characteristics of complexity such as heterogeneity of stakeholders and environmental contexts, interdependent relationships between actors across a variety of levels, and dynamic change processes that may take time to produce results, while occurring in environments that also change over time. What follows is a set of practical approaches for evaluating complex behavior change interventions.

Participatory Evaluation

An evaluator facilitates the evaluation process by engaging key stakeholders in a variety of ways, ranging from their limited involvement mainly as data sources to information sharing, consultation, or empowered decision making. Participatory evaluations involve stakeholders in meaningful ways in all facets of the evaluation; this is considered important as the first step in any evaluation (Milstein and Wetterhall 1999; Preskill and Jones 2009). Engaging stakeholders is even more important when evaluating complex interventions that involve multiple actors, each working under her own set of goals and within her own system (Cabrera et al. 2008). The need to understand the different perspectives of stakeholders and establish common goals for the intervention and the evaluation is paramount (Cabrera et al. 2008; Leischow and Milstein 2006; Regeer et al. 2009).

Stakeholder participation is so critical to a systems approach to evaluation that it gets fundamentally reframed by Patton (2011) in his articulation of developmental evaluation. In developmental evaluation, the evaluator is embedded in the intervention in order to lend evaluative thinking as the intervention is developed and evolves. Rather than considering the evaluator as working with program sponsors to bring in stakeholders, the evaluator is part of the intervention team, thereby becoming a stakeholder himself. An embedded evaluator can better surface assumptions, understand and reveal system heterogeneity, and bring data to decision making.

Intervention and Its Context

In systems-based evaluation, evaluators must not only thoroughly understand the intervention being evaluated, but must also understand
the context in which it is being implemented. To this end, situation analysis has become a standard of practice in both planning and evaluation (Stevahn et al. 2005). Pawson and Tilley (1997) further emphasize the importance of context in their account of realistic evaluation, a sociologically grounded approach by which the evaluator attempts to account for the complex social reality in which interventions are embedded. In the example of a smoking cessation program aimed at teens, understanding the intervention and the context could include consideration of the boundaries and scope of the intervention itself, the multiple settings in which teens might make smoking decisions in their day-to-day lives, the role of other actors within those settings in influencing those decisions, and the presence or absence of structural supports to encourage behavior change (Douglas et al. 2010). This approach further demonstrates the importance of stakeholder participation, insofar as stakeholders are key informants on their own social and personal contexts.

Understanding the context and change mechanisms of the intervention, in addition to developing a full understanding of the elements that are implicated in the behavior change, enables the evaluator to set the stage for facilitating decision making around the focus of the evaluation, the methodologies chosen, and the interpretation and use of the results (Hargreaves 2010). A variety of modeling techniques have been used to gain a comprehensive understanding of the intervention and its context. The most commonly used and best known to most evaluators is through the development of logic models, but there are other types of models and group model-building processes that can provide additional insight. These include path analysis, flow-through diagrams, and causal loop diagrams (Smith 1990; Spector et al. 2001; Ven-nix 1999). These models will aid the evaluator in accounting for the complex characteristics of the system at hand, including its heterogeneity and interdependencies.

Relationships, Structures, and Feedback Mechanisms

To understand the context of an intervention and reveal the deeper layers of complexity embedded in the system under study, it is important to focus on relationships and interdependencies as well as the structures and feedback loops that support them. As Meadows argues, “once we see the relationship between structure and behavior, we can begin to understand how systems work, what makes them produce poor results, and how to shift them into better behavioral patterns” (Meadows and Wright 2009). In other words, understand the relationships among actors in the system, among program components, and among levels of the system.

Populations are highly adaptable, self-organized systems that both respond to changes in, and exert changes upon, the context in which they live. Evaluators familiar with system concepts accept that this characteristic of self-organization will challenge standardization of an intervention and implementation fidelity. Interventions that are designed with complexity in mind attempt to facilitate self-organization by creating the conditions for it to flourish, in part through the development of relationships between actors within subsystems and between actors across systems (Catsambas et al. 2008; Parsons 2009). The importance of understanding self-organization is a common feature of system approaches to evaluation (Cabrera et al. 2008; Catsambas et al. 2008; Coffman 2007; Leischow and Milstein 2006; Williams and Hummelbrunner 2010).

Theory of Change

Good evaluation (and program planning) practice seeks to understand the theoretical basis for the program and the change envisioned, and then model them for the evaluators and stakeholders. This is even more important and
challenging in complex interventions, in which a traditional reliance on relatively linear models may fall short (Pawson 2006; Rogers 2008). Theory can be incorporated into evaluation and program planning in numerous ways, ranging from implementation theories, to specific program and behavior change theories, to diffusion and dissemination theories. Like other dynamic aspects of complex systems, the theories themselves are also negotiated and renegotiated throughout the intervention (Pawson 2006). Logic models, as mentioned, are the most common way to begin unpacking the underlying assumptions about change, but, as others have pointed out, they may lack clarity on what happens between the columns or lines (i.e., between the activities, outputs, and outcomes) (Dyehouse et al. 2009). Other theory-focused techniques enable program stakeholders to use logic models to articulate in a nonlinear fashion how the intervention will bring about the desired changes (Rogers 2008). Weitzman and colleagues (2009) combined quasi-experimental methods with theories of change as part of the validation process for the evaluation of a multisite comprehensive citywide health initiative. Further work is needed to adapt existing approaches to program theory to meet the needs of evaluation that respects the growing complexity of interventions enabling behavior change in populations.

Focus on Contribution Rather than Attribution

Our last consideration for evaluating from complexity involves a focus on contribution (what plausibly might account for change) rather than attribution (what is directly responsible for change) (Mayne 2001). Because complex systems have nonlinear dynamics, predicting with any degree of certainty the causal relationships between any particular program and long-term outcomes, such as national obesity rates, is usually impossible (Pawson 2006). Instead, when working in a complex system, the focus should be on contribution rather than attribution. Mayne and others offer a multipronged approach called contribution analysis for making the links between the intervention and the more distal outcomes that are influenced by multiple factors beyond the intervention (Brown Urban and Trochim 2009; Mayne 2001). The central idea is that evaluation should measure what it is directly trying to change (i.e., short-
Conclusion

In sum, behavior change interventions that acknowledge complexity can maximize the learning from evaluation by involving stakeholders, developing a solid understanding of the intervention and its context, studying relationships among actors, articulating a theory of change, studying both process and outcomes, and focusing on contribution to outcomes rather than attempting to make causal connections between the intervention and more distal outcomes. Evaluation with a complexity lens does not require a whole new set of skills for evaluators; rather, it calls for acknowledging and incorporating system dynamics and including some well-established evaluation approaches and tools. Evaluators who do these things will be better equipped to provide a comprehensive understanding of the behavioral intervention and contribute to the understanding of why it did or did not bring about the anticipated results. As stated at the beginning of this chapter, understanding, influencing and evaluating behavior change will be facilitated through an improved understanding of complex systems theory and the adoption of complexity into practice.

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Stages of Change (SOC)  a framework to assess an individual’s readiness to implement a new, healthier behavior; the framework provides strategies to guide the individual through the five stages: precontemplation, contemplation, preparation, action, and maintenance; part of the Transtheoretical Model (TTM).

stakeholders  individuals or groups who have an investment or a stake in the outcome of a program and therefore have reasons to be interested in the evaluation of the program.

statistically significant  not occurring randomly, instead more likely to be attributable to a particular cause.

stereotype  an oversimplified but widely held conception, often derogatory.

stigma  a mark (figurative in this context) of disgrace.

stigmatization  characterization as disgraceful.

stochastic system  a process with an element of randomness that leads to a degree of uncertainty about the outcome.

strategy  a plan of action that anticipates barriers and resources in relation to achieving a specific objective.

stratification  arranging into hierarchical classes.

structural determinant  a factor influencing health that is external to the individual patient’s control (e.g., public policies that influence tobacco use through modification of physical environments in which tobacco use can occur).

structural equation  a statistical analytic technique for testing and estimating causal relations using a combination of statistical data and qualitative causal assumptions.

structural interventions  programs targeting factors outside the individual’s control.

subjective norms  perceived social pressure to engage or not to engage in a behavior.

successive approximations  steps taken to achieve a certain behavior, with each step seen as a small success to increase confidence and motivation for the next step.

surveillance  periodic measurement, collection, and analysis of data on events or observations in a whole population.

synergy  the interaction of two or more agents to produce a combined effect greater than the sum of their separate effects.

system  a set of interlocking relationships such that change in one part results in changes in other parts, with feedback to the part that first changed, resulting in further change there to establish equilibrium.

system dynamics  an approach to understanding complex system behavior over time, involving internal feedback loops.

systems approach (thinking)  a theory that emphasizes the interdependence of all parts of the system.

systems science  an interdisciplinary field that studies the nature of complex systems in nature, society, and science.

tailoring  using information about an individual to shape the message or other qualities of a communication or other intervention so that it has the best possible fit with the factors predisposing, enabling, and reinforcing that person’s behavior; see also segmentation.

targeting  understanding population health trends to prepare a provider to work with various types of patients; this approach is distinct from tailoring in that it uses information about a person’s characteristics but without detailed individualized assessment.

target population  an intervention’s intended audience.

task ambiguity  lacking a mechanism to clarify and communicate goals to those intended to carry out the task.

taxonomy  classification in an ordered system that indicates natural relationships.

tertiary prevention  measures taken after a disease has occurred to slow it down, treat damage/pain, and prevent complications; see also primary and secondary prevention.

testability  the ability of a theory to be used to generate hypotheses that can be supported or fail to be supported through empirical research.

testing effect bias  a study confounder/threat to internal validity in which learning results from taking a pretest, causing the participant to perform better on a posttest, not because the individual changed as a result of the intervention, but because he or she remembers information from the pretest.

theory  a set of interrelated concepts, definitions, and propositions that present a systematic view of events or situations by specifying relations among variables, in order to explain and predict the events or situations.

Theory of Planned Behavior (TPB)  a notion originating from the theory of reasoned action
that people’s behaviors are influenced by their beliefs about the consequences of their actions and the expectations of others.

**Theory of Reasoned Action** a social cognitive theory of the relationships between attitudes and volitional behavior in which intention is the immediate determinant of behavior and that intentions are determined jointly by attitudes toward the behavior and perceived social pressures to engage in the behavior.

**theory of the problem** see explanatory theory.

**therapeutic communities** long-term residential settings with a strong emphasis on the use of community to enact long-term change.

**Transtheoretical Model (TTM)** a model that describes how people modify a problem behavior or acquire a positive behavior; the central construct of the model is Stages of Change.

**treatment group** a set of research participants undergoing the experiment (i.e., receiving the treatment).

**trialability** whether something can be tested or tried out with relative ease.

**triangulation** using data from three sources so that if two are inconsistent, the third provides a tie break.

**trigger** an event or thing that prompts a behavior, for example, a dish of candy; often described as leading to or causing a decision to “just do it.”

**under-weighting** placing scant significance on outcomes.

**unpredictability** not able to be foreseen.

**validity** the quality of having a logical basis.

**value** a preference shared and transmitted within a community.

**vector** a term from epidemiology that describes an organism that transmits a disease or parasite from one animal or plant to another; also known as an agent.

**walkability** a measure of how conducive an area is to walking within it.

**wellness** a health dimension beyond the absence of disease or infirmity, including social, emotional, and spiritual aspects of health.

**whole network** a group of three or more organizations connected in ways that facilitate achievement of a common goal and are formally established and governed (i.e., do not occur randomly).

**wisdom literature** a body of knowledge that captures the experiences of practitioners.

**workplace health promotion** a subset of employee-oriented health programs in work sites that pertain particularly to the behavioral and environmental changes necessary to effect the prevention disease and the promotion of health.

**wraparound services** services that address multiple life domains across home, school, and community, including living environment; basic needs; safety; and social, emotional, educational, spiritual, and cultural needs.

**years of potential life lost (YPLL)** estimate of the average additional years a person would have lived if she or he had not died prematurely.