CHAPTER 2

Psychophysiological and Systems Perspectives on Stress and Stress Management

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THE NATURE OF STRESS

What is stress? It is both a stimulus and a response. As a stimulus, it involves a cue or series of cues signaling a need to prepare for danger or for action. We may think of these cues and the responses to them as simple Pavlovian conditioning effects, in which the "conditional response" is the body's preparation to respond to an anticipated physical need to think faster and/or to act. By themselves, these "calls to action" may not be sufficient to be considered "stressful," unless they are accompanied by unpleasant symptoms, elevated risk for illness, or impairment in function. Indeed, they are part of everyday life and are responsible for our ability to work, perform, and think more productively when needed. The responses may include increased blood flow to the brain, nervous system, and muscles that increases neuromuscular efficiency and strength, improves thought processes to prepare strategies for coping with danger, increases inflammatory activity to fight invasion of microbes, and increases the efficiency of various modulatory responses that prevent stress reactions from hurting the body. Such modulatory reflexes act to limit the mobilization and inflammatory responses to prevent self-injury. Poor and dysfunctional regulation of stress responses may occur when stress stimuli are too severe or prolonged, or when coping behaviors and reflexes are insufficient to manage the stress stimuli and the body's responses to it. Stress-induced dysregulation is responsible for a large number of both physical and psychological ailments (see Table 2.1). This book is a compilation of empirically validated methods that help strengthen cognitive and psychophysiological processes involved in coping with stress.

In modern society, many stress stimuli are social. Social stressors usually do not require the type of physical mobilization required by our ancestors who were dealing

TABLE 2.1. Conditions Exacerbated by Stress

Mental/emotional conditions	Physical conditions

• Anxiety disorders
• Depression
• Schizophrenia
• Eating disorders
• Behavioral disorders
• Personality disorder
• Anger disorders
• Somatization/hypochondriasis
• Tourette syndrome
• Insomnia
	• Asthma
	• Arthritis
	• Hypertension
	• Various pain syndromes
	  ○ Headache, TMJ
	• Irritable and inflammatory bowel
	• Raynaud's disease
	• Cancer
	  ○ Chemotherapy side effects
	  ○ Disease progression
	• Stress of mechanical ventilation
	• Diabetes
	• CPAP adherence
	• Postsurgery wound healing
	• Parkinson's disease
	• Infectious disease
	• Allergy
	• Atherosclerosis and heart disease
	• Unexplained symptoms
	• Pain and somatic problems in general

Note. Data from citations in PsycInfo (American Psychological Association, 2020) and Medline (National Library of Medicine, 2020).

with saber-toothed tigers, so the physical mobilization produced by stress responses often is not particularly useful to us, but it occurs anyway as a vestige of our ancient past as a species. The sociological and social psychological literature describes stress symptoms associated with low social status, including such factors as poverty, crime, racial or ethnic discrimination, and so forth (Hollingshead & Redlich, 1958; Merton, 1938; Pearlin, 1969; Srole, Langner, Michael, Oplear, & Rennie, 1962). Lower rank in organizational hierarchies also increases vulnerability to stress (Luceno-Moreno, Garcia-Albuerne, Talavera-Velasco, & Martin-Garcia, 2016; Martins & Lopes, 2012; Shirom & Mayer, 1993). Although having a lower institutional rank may cause stress through lower levels of control of one's work environment, there is some evidence that an individual's *perception* of low social status may contribute to stress, whether or not this corresponds to more objective measures (Fales, 2018; Han, 2014; President, 2017; Sabik, Falat, & Magagnos, 2020; Scott et al., 2014). Minority groups and lower-socioeconomic status groups are particularly vulnerable to stress effects in the absence of protective family and community conditions. Individual psychological, social, and environmental factors also play a role in stress vulnerability. These could include isolation, poor family coherence, changing role expectations (e.g., changing sex- and age-role expectations over time, culture clashes for both immigrants and hosts), effects of economic swings and risks of unemployment, effects of natural disasters and social upheavals, poor or inadequate diet, deprivation of daylight, family mental illness and abuse, and so forth.

A survey by the American Psychological Association (2017) found that concerns about health care and the economy topped the list of stress sources, along with some other items related to current political debates in a turbulent political time in the United States. (See Table 2.2.) Presumably the concerns for 2020 will relate to the stresses induced by the COVID-19 pandemic, including fear of disease, economic dislocation, social isolation, exacerbation of household relationship problems, switch from live to

TABLE 2.2. Sources of Stress

Source of Stress	% of Responders
Health care	43
The economy	35
Trust in government	32
Crime and hate crimes	31
Terrorist attacks	30
High taxes	28
Unemployment/low wages	22
Climate change/environment	21

Note. Data from *www.apa.org/news/press/releases/stress/2017/state-nation.pdf*.

online methods for working, shopping, and socializing, and other stress sources yet to be identified.

There also is considerable evidence that exposure to severe stress early in life creates more vulnerability to stress symptoms in adulthood (Favaro, Tenconi, Degortes, Manara, & Santonastaso, 2015; van den Bosch, Dijk, Tibboel, & de Graaff, 2017), perhaps because the body becomes attuned to expect conditions that require psychobiological readiness to adapt to stressful conditions. It may come to expect a need for greater alertness, sensitivity to cues for danger, and physiological preparation for behavioral mobilization as well as the need to cope physiologically with injury. It is also possible that these characteristics can be transmitted intergenerationally, either from in utero learning or epigenetic changes (Fogelman & Canli, 2019; Guillen-Burgos & Gutierrez-Ruiz, 2018; Voisey, Young, Lawford, & Morris, 2014). There is evidence that in utero exposure to violence and other stressors experienced by the mother can create greater incidence of allergy and asthma in the offspring (Lee et al., 2018; Magnus et al., 2018; Wright et al., 2004). It is known that inflammation and elevated immune reactions are characteristic of the stress response, leading to such autoimmune symptoms when the body's coping mechanisms are overwhelmed, as described in Chapter 4 of this volume by Kusnecov, Norton, and Nissenbaum. The need to adapt to severe stress in subsequent generations could contribute to species survival in stressful environments and would be consistent with possible epigenetic changes caused by prenatal exposure to stress.

HARDINESS

The correlation between exposure to stressors and occurrence of stress symptoms is far from perfect. Although various conditions lead to higher rates of illness and feelings of discomfort, some people seem to remain unscathed. A concept used to explain this discrepancy is "hardiness." Some people appear to take exposure to stressors more in stride than do others (Maddi, 2017; Maddi et al., 2017; Pitts, Safer, Russell, & Castro-Chapman, 2016; Stoppelbein, McRae, & Greening, 2017). Although psychological research on hardiness has tended to focus mainly on such social buffers as cohesiveness and support (Kuzmin & Konopak, 2016; Zeer, Yugova, Karpova, & Trubetskaya, 2016), biological factors also play a role (McVicar, Ravalier, & Greenwood, 2014; Oken, Chamine,

& Wakeland, 2015; Parkash, Archana, & Kumar, 2017). Longitudinal developmental research has shown that some infants show greater levels of autonomic and emotional reactivity than others and that these correlate, however imperfectly, with greater emotional reactivity later in life (Berry, Blair, Willoughby, & Granger, 2012; Cohen, 1989; Raby, 2016; Wagner et al., 2017). Some people are more resilient, perhaps showing transient effects of strain but bouncing back to relative equanimity most of the time.

SPECIFIC TREATMENTS FOR PARTICULAR SYMPTOMS OF STRESS

The kinds of stress-related symptoms that people experience can differ. An interesting experiment by Peter Lang in the 1960s provides a useful way of classifying some of these differences. In a study of people who were afraid of snakes, participants were told to approach a caged harmless snake, to pick it up, and to play with it. He measured their physiological arousal as reflected in heart rate and skin conductance, their expressed fear, and how close they actually came to the snake. He found these measures not to be highly correlated with each other. He concluded that three dimensions of fear are partially independent of each other: physiological, cognitive, and behavioral. He advised that each of these dimensions be given specific attention in treatment for stress-related problems (Lang, 1968, 1979), and that some people may need more attention paid to one dimension than to another. Some people are constitutionally more physiologically reactive or have had illnesses (Menard, Pfau, Hodes, & Russo, 2017; Porcelli, Laera, Mastrangelo, & Di Masi, 2012) or life experiences (Engert et al., 2010; Goodman & Brand, 2009; Gunnar & Vazquez, 2006; Uchida et al., 2010) that make them more physiologically sensitive. Some people tend to think of the world and their life situations as more threatening than do others and have less "self-efficacy" for managing their problems (Chung, AlQarni, Al Muhairi, & Mitchell, 2017; Delahaij & Van Dam, 2017; Lavenda & Kestler-Peleg, 2017; Troesch & Bauer, 2017). Some people are less skillful than others in managing their problems or managing particular job or social demands (Fadirepo, 2013; Faul, Jim, Williams, Loftus, & Jacobsen, 2010; Harvey, Harris, Harris, & Wheeler, 2007; Jordet, Hartman, Visscher, & Lemmink, 2007; Zhang et al., 2014). When looking at diagnostic classifications of anxiety disorders by the psychiatric profession (American Psychiatric Association, 2013), these three dimensions neatly correspond to specific anxiety diagnoses: panic disorder on the physiological dimension, characterized by the physiological symptoms of panic, generalized anxiety disorder on the cognitive dimension, characterized by exaggerated and pervasive worry, and phobic disorders on the behavioral dimension, characterized by behavioral avoidance.

More highly specific treatment tailored to the particular system displaying the problem can sometimes produce larger beneficial effects. Although cognitive and behavioral interventions can produce psychophysiological relaxation (Abelson, Neese, Weg, & Curtis, 1996; Hofmann, 1999; Lundgren, Carlsson, & Berggren, 2006), these effects are not consistently reported (Michelson et al., 1990), suggesting that in some cases a more psychophysiologically focused treatment may be more powerful for treating psychophysiological symptoms of stress. Even biofeedback procedures to train one specific muscle group (usually the frontalis muscle) often do not generalize to greater relaxation in other muscles (Thompson, Haber, & Tearnan, 1981), so a single psychophysiological approach may not even be the most beneficial approach for all psychophysiological problems. Similarly, cognitive interventions may be expected to have specific effects on thoughts, behavioral interventions on coping efficacy.

Although there are few head-to-head comparison studies of these modalities on specific outcomes and considerable evidence for cross-modality improvements, there is some evidence for symptom-treatment specificity. In a meta-analysis of breathing therapies for anxiety symptoms, we recently found a large effect size for panic symptoms, a moderate effect size for general anxiety symptoms, and a small effect size for phobias and posttraumatic stress disorder (PTSD) symptoms (Lehrer et al., 2017). Exposure therapies have been found to have greater effects than relaxation or cognitive therapies for treating phobic disorders, although the latter do have some therapeutic effect (Da Costa, Sardinha, & Nardi, 2008; Gilroy, Kirkby, Daniels, Menzies, & Montgomery, 2000; Otto, Hearon, & Safren, 2010). For generalized anxiety disorder, cognitive-behavioral therapy has been found to have a small and inconsistently greater effect than relaxation therapy (Donegan & Dugas, 2012; Kushner et al., 2013; Norton, 2012).

FOCUS OF THIS VOLUME: PSYCHOPHYSIOLOGICAL STRESS TREATMENTS

In this volume, we focus primarily on interventions with a strong psychophysiological focus, although we also include chapters describing cognitive and behavioral interventions. We do this because the psychophysiological dimension is one that often is shortchanged in both training and practice of modern psychotherapists. This volume contains chapters for each modality written by leading practitioners of those modalities.

For better or worse, modern treatment of stress-related conditions often is relegated to providers associated with medical care, where treatment most often is pharmacological. This volume deals with nonpharmacological alternatives. However, even independent nonmedical psychotherapists who eschew the "medical model" of emotional disorders still function in a medically dominated system, at least to the extent that their incomes are often dependent on medical insurance and the classification of emotional problems as forms of illness. Although the growth of the "life coach" industry may be an exception to this tendency, and although teachers, coaches, and counselors have long contributed their skills to building stress resilience, the ways in which we treat stress-related problems have long been influenced by medical conceptualizations, from the time of Hippocrates and the ancient Greeks (Chrousos, Loriaux, & Gold, 1988) through psychoanalysis (Cleghorn, 1965; Hruby, Hasto, & Minarik, 2011; Kimball, 1983) and the current reliance on the *Diagnostic and Statistical Manual of Mental Disorders* (DSM) system for conceptualizing "mental diseases" (Padmanabhan, 2017).

Although in earlier days many of the medical approaches overlapped the psychophysiological approaches described in this volume, the advent of modern psychopharmacology has accentuated chemical treatment of emotional problems, with psychophysiological interventions playing a minor and often insignificant role. The advent of psychoanalysis produced a temporary change in this pattern, so helping people to understand unconscious conflicts and wishes became seen as a medical specialty. Nevertheless, advocates of psychoanalysis and some of the other methods described in this book, particularly autogenic training, advised that practice of these methods be restricted to physicians. However, from the early papers by Freud on "lay analysis" (Freud & Eitingon, 1927), nonmedical practitioners of psychoanalysis played increasingly important roles in the practice and development of this and associated methods, and although psychoanalytical treatments are no longer considered the exclusive province of psychiatrists, the practice of psychotherapy retains a medical stamp, and people who treat stress-related problems almost always justify insurance reimbursement by referring to the American Psychiatric

Association's taxonomy of emotional problems in the DSM manuals (e.g., American Psychiatric Association, 2013).

The behavior therapy movement was a reaction among psychologists to this medical approach and sought to use the science of human behavior rather than, as in psychoanalysis, clinical experience to guide practice. The later development of cognitive-behavior therapy (CBT) imported from psychoanalytic therapy some of the understanding of thought patterns in emotional problems (Beck, 2004; Ellis, 2005) and targeted them more directly in a behavior modification framework. However, in many circles, "cognitive-behavioral therapy" has become almost exclusively a form only of *cognitive* therapy, with psychophysiological and even behavioral dimensions falling by the wayside. More recently, behavioral techniques have gained some resurgence, such as in the practice of exposure therapy for anxiety disorders and behavior activation for depression (Ahs, Gingnell, Furmark, & Fredrikson, 2017; Braun, Gregor, & Tran, 2013; Collins & Coles, 2017; Hofmann, Mundy, & Curtiss, 2015; Hopko & Lejuez, 2007; Jayasinghe et al., 2014; McGuire et al., 2012; Ramnero, Folke, & Kanter, 2016; Williams, Crozier, & Powers, 2011). However, psychophysiological approaches still play only a minor role, with many CBT practitioners having little or no training in these methods (cf. current texts for training in behavior therapy; e.g., Spiegler & Guevremont, 2016). The emphasis in this book on psychophysiological approaches is an attempt to restore the balance among techniques for treating cognitive, behavioral, and psychophysiological aspects of emotional problems by providing a number of chapters in the various empirically validated methods of psychophysiological interventions.

So, then, what do these psychophysiological interventions target? The targets are improving regulation and resilience.

REGULATION

Popularly, stress-related problems are often measured as *too much* or *too little* of some psychophysiological dimension: high or low levels of blood pressure, elevated muscle tension, exaggerated startle reactivity, and so forth. These can be manifested in such physical conditions as hypertension, muscular aches and pains, insomnia, constipation, low sexual desire or impaired performance, loss of appetite, various anxiety conditions, and more. They are all manifestations of the well-known "fight or flight" reaction, in which the sympathetic branch of the autonomic nervous system predominates and inhibits the opposing influences of the parasympathetic nervous system, which has been characterized as the "rest and digest" system and which lowers heart rate and blood pressure, fosters feelings of relaxation, increases gastrointestinal activity, facilitates sexual arousal, and other effects. Because sympathetic overarousal is often one of the predominant symptoms of stress, many stress management methods specifically target decreasing sympathetic activity, sometimes accompanied by ways of increasing parasympathetic function (Bali & Jaggi, 2015).

However, the body's system of autonomic control is much more complicated than this. Some stress-related symptoms are parasympathetic, not sympathetic. These include symptoms of fatigue, fainting, gastric hyperacidity, diarrhea, asthma, hypersexuality, and overeating. In some cases, the predominant stress response is parasympathetic. For example, some people with blood phobias faint when exposed to the sight of blood (Engel, 1978), although there is some evidence that this is an exaggerated parasympathetic rebound reaction after initial sympathetic arousal (Dahllöf & Öst, 1998; Ritz, Meuret,

& Simon, 2013). Most organisms, including people, freeze or faint when exposed to severe, life-threatening, and unavoidable stress, although it also has been hypothesized that such freezing occurs when a threat is at a distance and alertness to external stimuli is needed, as well as in individuals who have been traumatized, perhaps having experienced unavoidable severe stress (Niermann, Figner, & Roelofs, 2017). Some people tend to be more parasympathetically tuned, such that they more readily show a parasympathetic rather than a sympathetic response when exposed even to more minor stressors. This is consistent with observations of the "orienting reflex" (Graham & Clifton, 1966), in which deceleration in heart rate is associated with greater perceptual acuity when the organism is stimulated to "take in" environmental information. There is some evidence that this reflex is characteristic of people with some parasympathetically mediated or activated disorders. We have found this in our own research on asthma, in which constriction of the smooth muscles in the bronchi is mediated by parasympathetic activity and in which exposure to some laboratory stressors produces a parasympathetic response along with bronchoconstriction, whereas other people tend to respond with sympathetic arousal and/or inhibition of parasympathetic activity (Feldman, Lehrer, Hochron, & Schwartz, 2002).

Adding to the complexity of parasympathetic involvement in the stress response is the phenomenon of parasympathetic rebound. As the great physiologist Ernst Gellhorn observed in his studies of the hypothalamus, the activating components of autonomic activity, which he termed *ergotropic,* tended to activate *reactivity* in the opposing system, which he called *trophotropic,* at the same time as the two systems tended to inhibit effects of the other (Gellhorn, 1959, 1967, 1968). Thus, although sympathetic arousal may inhibit some parasympathetic functions (digestion, relaxation, etc.), parasympathetic functions become more hair-triggered. Thus, after sympathetic arousal subsides, parasympathetic symptoms often break out. These can include such common events as postexamination fatigue in students, nocturnal asthma or gastrointestinal symptoms, hunger, and increased sexual desire after sympathetic activity has suddenly decreased. We have found that following a period of muscle relaxation, parasympathetic activity increases in asthma patients, including a tendency to parasympathetic bronchoconstriction (Lehrer et al., 1997), suggesting that muscle relaxation might not be a good recommendation during an acute asthma attack. Sometimes the reactivity is so powerful that it overwhelms the inhibitory effects of sympathetic arousal, such that both sympathetically and parasympathetically mediated events may occur simultaneously, such as diarrhea, hunger, asthma, fatigue, or even sexual arousal occurring during a period of intense stress (DeGood & Williams, 1982; Harrison, Jones, Hughes, & LeFevre, 2013; Lazarus & Mayne, 1990; Lee et al., 2016; Mandell, 2017; Manto, 1969; Overmier, Murison, Ursin, & Skoglund, 1987). In some cases, the parasympathetic component in the stress response may facilitate the "play dead" response to overwhelming stress described above.

Just as parasympathetic arousal is not always "good" in the context of stress management, sympathetic arousal is not always "bad." It is important for producing feelings of vigor and energy after waking up, for maintaining muscle tone, and for maintaining sufficient blood pressure and proper function of all organs that the sympathetic system innervates. Thus to think of stress management as directed at reducing sympathetic arousal and/or increasing parasympathetic arousal is an oversimplification. The important concepts here, then, are *regulation* and its opposite, *dysregulation*. The body is composed of multiple systems that maintain a proper balance, allow us to respond to various external demands, and return to a healthy and asymptomatic state. These systems regulate the body. When symptoms occur, the body is *dysregulated*. The target, then, of stress management is dysregulation: how to prevent and remedy it.

THE CYBERNETICS OF REGULATION AND DYSREGULATION

In discussing regulation and dysregulation, it is useful to draw on some cybernetic concepts, often more in the province of systems engineers than of psychologists and psychophysiologists. Here we review concepts of *control systems*, positive and negative *feedback loops*, and both *open* and *closed* system control (Lehrer & Eddie, 2013).

A *system* is defined as an entity that has its own characteristics, independently of its component parts. Thus the cardiovascular system is more than cardiac output and blood pressure fluctuations, just as the norms by which family members relate to each other are built of more than the sum of personality types of individual family members, and as cell behavior differs from component chemical processes that guide cellular behavior.

A *control system* is a system that contains various internal processes that keep the system operating properly, even when various environmental perturbations may act to change or destroy system function. Thus various guidance systems have mechanisms to maintain a predetermined course of an aircraft, and gasoline supply to modern motor engines is regulated based on the engine's need for fuel. The body has hundreds of control systems. The reciprocal relationship between the sympathetic and parasympathetic systems is just one of them. Others control almost all aspects of psychological and physiological function—for example, sleep–wake cycles (Fisher, Foster, & Peirson, 2013); respiration (Aittokallio, Gyllenberg, Polo, & Virkki, 2007; Guz, 1997; Krimsky & Leiter, 2005); hunger cycles (Blundell et al., 2012; Cheung, Ko, Chow, & Kong, 2018; Mithieux, 2013; Read, 1992); immune system fluctuations (Hirayama & Okita, 2000; Wong & Germain, 2017); cardiovascular system control (Batzel & Bachar, 2010; Mainardi, Bianchi, & Cerutti, 2002); and even social system control (Bhatti & Channabasavanna, 1979; Daniels, Krakauer, & Flack, 2017; Geist, 1986; Michener, 1987; Wright & Meyer, 1978). The healthy individual shows sympathetic or parasympathetic dominance where appropriate: hunger and satiety, elevated or depressed immune system function, variations in types of social interactions among friends, associates, and lovers.

Heart rate variability is a quintessential example of a multiplicity of control systems in the body. Chaos in the pattern of heart rate variability is a strong correlate of resilience (Karavirta et al., 2013; Lefebvre, Goodings, Kamath, & Fallen, 1993; Li & Yuan, 2008; Poon, 1999; Wayne et al., 2013). This is understandable if we think of *chaos* not as random variability, but as reflecting the action of many control systems in the cardiovascular system, all acting simultaneously with differing frequency characteristics. With more control systems as "backups" for each other, the greater the resilience should be for the cardiovascular system as a whole.

Control systems are usually made up of multiple *negative feedback loops*. A negative feedback loop exists when one process modulates variability in another. The body has hundreds of them. One example is the baroreflex. This reflex controls blood pressure (Eckberg & Sleight, 1992) and, indirectly, through brainstem projections to the limbic system, emotional reactivity (Henderson et al., 2004; Mather & Thayer, 2018). The baroreflex acts through stretch receptors in the aorta and carotid arteries. When blood pressure rises, the baroreflex acts to decrease heart rate and expand the blood vessels. The opposite occurs when blood pressure falls. The two loops (heart rate and vascular tone) function with different frequency characteristics (Vaschillo, Lehrer, Rishe, & Konstantinov, 2002; Vaschillo, Vaschillo, Buckman, Pandina, & Bates, 2012), thus contributing to the chaotic nature of heart rate variability. Both, however, help maintain blood pressure at a healthy level. Stimulation and strengthening of the baroreflex is the primary mechanism underlying the effects of heart rate variability biofeedback (Chapter 10 of this volume by Lehrer). Such negative feedback loops occur from the cellular level to the social systems level, helping to provide stability and modulating change in such a way that the systems do not disintegrate. They maintain body temperature, mood, various personality characteristics, marriages, and even whole societies.

This description of negative feedback loops assumes that the system is entirely self-maintaining and does not need external help to maintain stability. A *closed loop* system does not depend on external influences in order to work. In cases of dysregulation, in which physiology, emotions, behavior, and so forth start acting maladaptively, closed loops do not appear to be adequate to maintain system stability. That is when some outside help is needed. Some of this help can come from various sources of social and material support or various forms of environmental stimulation. For example the baroreflex is exercised by the presence of gravity and effects of normal exercise on the baroreflex system. Advice, insight, and social support can help people to act more adaptively and correct fluctuations in mood or anxiety. Sometimes special stress management techniques are needed. This book describes many ways in which various empirically validated stress management methods, from relaxation exercises to cognitive restructuring, can help to restore stability. Systems that habitually rely on such external influences for stability are called *open loop* systems. Most of human behavior is regulated by open loop as well as closed loop systems, which work synchronously to adapt to environmental demands while preserving internal integrity (Lehrer & Eddie, 2013). All of us, therefore, can make good use of the methods described in this book.

Positive feedback loops also have their place in maintaining stability (Avendano, Leidy, & Pedraza, 2013; Cinquin & Demongeot, 2002; Lehrer & Eddie, 2013). In these loops, activity in the system generates more of the same activity, rather than limiting it. Thus, when we exercise or are under threat, the sympathetic nervous system activates, and various parts of the system (e.g., muscle tension) act to further increase this arousal. When we are anxious about one thing, we often start worrying about other things as well, thus increasing our level of alertness—an adaptive strategy in times of danger. But when dysregulation occurs, these positive feedback loops can lead to tension-related physical problems and emotional disorders. Relaxation can have a modulatory effect through an open loop process. Thus the rationale for "progressive" muscle relaxation is that generalization sometimes does occur from relaxation in one muscle area to others (a positive feedback loop), and general muscle relaxation lowers sympathetic arousal (see McGuigan and Lehrer, Chapter 7, this volume). On the other hand, prolonged lack of exercise, as often happens in illness, can lead to fatigue, disability, and atrophy of reflexes needed for healthy physiological and emotional regulation.

A systems perspective thus lends some perspective to the role of stress in health and illness. Although too much stress can overload the body's ability to adapt, a certain amount of stress may be necessary to promote healthy adaptation. Only by exposure to difficulties do we develop skills to manage them. Only by responding to stressors do the reflexes that modulate stress become exercised and tuned. Positive feedback loops may exaggerate various stress responses, but they also exercise negative feedback loops that control these responses. Cannon's early description of homeostasis appeared in a book entitled *The Wisdom of the Body* (1932). True wisdom requires an endless capacity for complexity.

ALLOSTASIS AND ALLOSTATIC OVERLOAD

Most theories of stress and stress management have been framed by Cannon's concept of homeostasis. The various control systems in the body are designed to keep the body in a constant state. When stressors occur, negative feedback loops act to restore functioning to a constant resting level. This concept was simultaneously introduced by the physiologist Claude Bernard as the *milieu intérieur* (Bernard, 1974). The problem with the notion of homeostasis is that it does not describe healthy functioning. If heart rate did not rise when we were undergoing a period of prolonged exercise, we would not function efficiently and might not even survive. Decreased heart rate variability is associated with a variety of somatic and emotional diseases. In very impaired individuals or in the at-risk fetus is a negative predictor of survival (see Lehrer, Chapter 10, this volume). Heart rate must be able to change in response to constantly changing environmental demand. Even in personality structure, we would consider constancy in emotional state to be a liability, as a sign of rigidity. Healthy people are sometimes happy and sometimes sad, sometimes suspicious and sometimes trusting, sometimes angry and sometimes calm. An individual whose baseline level is only one of these could easily fit into one of the DSM categories of mental illness.

Add to this a cardinal characteristic of negative feedback loops: oscillation (Cinquin & Demongeot, 2002). When sympathetic arousal gets too high, parasympathetic arousal brings it down. When parasympathetic activity is too active, sympathetic activity emerges. This has a certain rhythm. Each of these autonomic branches also has its own multiple internal rhythms, including diurnal rhythms, monthly rhythms, seasonal rhythms, and so forth (Haim, Downs, & Raman, 2001; Lo et al., 2017; Varga & Heck, 2017). Heart rate and brain functions oscillate in intervals varying from milliseconds to minutes. So do moods and rhythms in relationships, with varying mathematical characteristics (Gottman, Murray, Swanson, Tyson, & Swanson, 2002).

This characteristic has been widely studied for heart rate. Heart rate variability is depressed in almost all physical and emotional illnesses, as well as in older age (Corino, Matteucci, & Mainardi, 2007; Mahinrad et al., 2016), in young infants (Eyre, Duncan, Birch, & Fisher, 2014; Jewell, Suk, & Luecken, 2018; Samper Villagrasa, Ventura Faci, Fabre Gonzalez, Bescos Pison, & Perez Gonzalez, 1989; Vigo, Guinjoan, Scaramal, Siri, & Cardinali, 2005), and in other conditions, such as illness, in which diminished resilience might be expected (Buchman, Stein, & Goldstein, 2002). It is elevated in people who are aerobically more fit (Alderman & Olson, 2014; Kaikkonen et al., 2014). Recent research has found that people are able to increase their heart rate variability through various voluntary control exercises, as in heart rate variability biofeedback (see Lehrer, Chapter 10, this volume). Heart rate variability also has been found to increase after CBT (Carney et al., 2000; Jang, Hwang, Padhye, & Meininger, 2017; Kim, Lim, Chung, & Woo, 2009), after various relaxation strategies described in this book (Huang, Hsieh, & Lai, 2016; McKenna, Gallagher, Forbes, & Ibeziako, 2015; Nijjar et al., 2014; Pal, Ganesh, Karthik, Nanda, & Pal, 2014; Wang, Dong, & Li, 2014), and after increased aerobic exercise (Castello et al., 2011; Dougherty, Glenny, & Kudenchuk, 2008; Marquis et al., 2008; Pigozzi et al., 2001; Raimundo et al., 2013; Shen & Wen, 2013), particularly where improvement in symptoms also occurs.

So, then, healthy stability is more characterized by organized *variability* rather than constancy, both in the resting state and in natural everyday life. This is the nature of allostasis (Karatsoreos & McEwen, 2011; McEwen, 2004, 2017). *Allostasis* connotes "stability through variability." Allostatic control requires adequate functioning of the various reflexes that mediate the many negative and positive feedback loops in the body. Although a moderate amount of exercise of these reflexes may help maintain their tone (thus illustrating how a moderate amount of stress might actually be good for us), too much strain on them can fatigue them and decrease their effectiveness. McEwen uses this concept in describing *allostatic overload,* in which the individual is faced with stress that is too great or too prolonged for the various negative control loop reflexes to function properly (Karatsoreos & McEwen, 2011; McEwen & Wingfield, 2003). These are the conditions in which various symptoms of stress appear, including disorders in mood, behavior, autonomic stability, and inflammation. As almost all body and emotional systems are controlled by regulatory processes, the failure of regulation that occurs with allostatic overload can be considered "dysregulation." Dysregulation, or allostatic overload, can occur because of severe and prolonged stress but also, in combination with these, by other impediments to effective regulation. These can include almost any form of physical disease, a physical or emotional predisposition to experience certain symptoms in response to minor stressors or challenges, or lack of resources or skills to manage the challenges that do occur. By definition, then, when dysregulation occurs, the individual experiences signs or symptoms of illness, impairment in functioning, or impaired quality of life due to discomfort, weakness, and other problems. Dysregulation is the hallmark of functional disorders, and stress is often implicated in producing it.

A variety of somatic diseases involve components of autonomic dysregulation. In the lungs, asthma (airway constriction); in the gut, irritable bowel syndrome (constipation or diarrhea) or chronic hyperacidity; in the cardiovascular system (hypertension or hypotension, fainting, vascular inflammation, heart attack, and more). When one branch of the autonomic nervous system becomes overactive and responses to stimulation are not sufficiently modulated, then symptoms occur. Healthy autonomic regulation is therefore demonstrated in a complex pattern of variability, reflecting the operation of multiple negative and positive feedback loops, often leading to a chaotic pattern of fluctuations. As mentioned above, *chaotic* does not mean "random"—randomness is a sign of disorganization, illness, and dysregulation. A chaotic pattern is a deterministic pattern governed by a complicated set of rules, which often can be described only by complicated combinations of nonlinear statistics, often characterized as "entropy" measures. For example, high degree of heart rate entropy (a measure of chaos in heart rate) predicts fetal survival in high-risk pregnancies (Ahearne, Boylan, & Murray, 2016; Frusca, Todros, Lees, Bilardo, & TRUFFLE Investigators, 2018), as well as survival in serious disease (Arzeno, Kearney, Eckberg, Nolan, & Poon, 2007; Halberg et al., 2000). A very simple pattern of heart rate variability, conversely, also indicates pathology, when one or two control reflexes predominate but others are inoperable.

Immune Dysregulation and Autoimmune Processes

The most influential 20th-century view of stress effects was proposed by Hans Selye, who likened the stress response to the body's response against invasive microbes (Selye, 1978). Stress is thus considered as a conditional reflex, designed to protect the body in anticipation of violation, perhaps in combat. This would be characterized by a heightened immune and inflammatory response, in which the body marshals resources to neutralize an invader (cf. Kusnecov and colleagues, Chapter 4, this volume), as well as, perhaps, a corticosteroid response that may be activated to modulate the inflammatory response when the threat is not great or prolonged, a reaction that can *depress* the immune reaction. Thus immune system dysregulation can be in the form of either a depressed or an overactive immune response. Cohen, Tyrrell, and Smith (1991) found that people experiencing psychological stress were more likely to catch cold when experimentally exposed to a rhinovirus than those reporting less stress. An overly active immune system could trigger an autoimmune response, as in allergy and asthma (Li et al., 2013; Miyasaka, Dobashi-Okuyama, Takahashi, Takayanagi, & Ohno, 2018; Miyasaka et al., 2016; Ohno, 2017). Interestingly, some epigenetic research has found a higher incidence of allergies and asthma among children whose mothers experienced severe environmental stress during pregnancy, showing that these tendencies may be carried on to future generations (Trump et al., 2016; Wright, 2007), where the bodies of offspring exhibit the preparatory response to threat of injury.

Social Systems Dysregulation

Social systems also tend to have regular and stable ways of acting. Much of social behavior reflects the influence of social norms that keep people behaving in expected ways. Sometimes normative regulations inflict some discomfort in individuals, as in family systems that include acceptance of abuse and societal systems that tolerate inequality and poverty. Disruptive behavior or severe stressors can make this discomfort intolerable and lead people to challenge social norms. Then the structure of the social system may change or even fall apart, as in divorce, internal warfare, or separatism. Patterns of interaction in marriage have been modeled mathematically (Gottman et al., 2002), and marital therapists are advised to help find alternative patterns that are already in a couple's repertoire and normative structure (Gottman & Gottman, 2008). With sufficient love and desire to maintain the marriage, some disagreements and discomforts can be overlooked in order to keep the marriage intact (Gottman & Gottman, 2017). Other social forces can even prevent therapeutic changes in social structures. When one person changes, as, for example, when one person in the family becomes less emotionally reactive or more assertive, others may get upset and sometimes act to restore the previous way of behaving. As in the famous *All in the Family* television show, attempts by Edith or the grown children to take on new, more assertive, and less conformative roles can be met with strong resistance from Archie, whose rampages are sometimes, but not always, successful in moderating some of the changes. Sometimes one person's becoming more relaxed and less reactive to stress may meet resistance in some quarters and often must be addressed in family therapy. Of course individuals' behavior and norms within the family and the culture at large do change, as demonstrated in the changing roles of women and minorities over the generations in most Western countries. This usually requires great and persistent effort on the part of social activists, or therapists. Although this volume does not include a chapter on social systems intervention, practitioners are wise to keep social control forces in mind as they implement other stress management methods.

Respiratory Dysregulation

A common form of stress-induced physiological dysregulation is in the respiratory system. The respiratory system is extraordinarily sensitive to demands on the body, both physical and emotional, actual or anticipated. When a real or anticipated demand for increased physical exercise or mental activity occurs, respiratory drive increases (Houtveen, Rietveld, & de Geus, 2002). This can be measured as the force of inhalation with each breath, as well as diaphragmatic muscle activity during inhalation (Garland, Doshi, & Turcanu, 2015; Kay, 1979; MacBean, Hughes, Nicol, Reilly, & Rafferty, 2016; Reilly et al., 2013; Reiterer & Muller, 2003). When increases in ventilation are matched with increased metabolic rate, then the oxygen–carbon dioxide balance in the body is maintained. When these are mismatched, various symptoms of respiratory dysregulation occur often in the form of hyperventilation.

The term *dysfunctional breathing* has been used to describe such patterns of dysfunctional breathing. Dysfunctional breathing can include a pattern of thoracic breathing and general excess muscle tension involved in respiration (Barker & Everard, 2015; Prys-Picard & Niven, 2008), often accompanied by decreased partial pressure of carbon dioxide in the blood. Through several well-known reflexes, this can produce decreased oxygen availability to tissues, which, in turn, can cause dysfunction throughout the body (see Meuret & Ritz, Chapter 11, and van Dixhoorn, Chapter 12, this volume). Although thoracic breathing and blood levels of carbon dioxide often do not correlate well with each other (Courtney, Greenwood, & Cohen, 2011), they both are related to a variety of physical and psychological symptoms. This may reflect an episodic nature for some hyperventilation problems, which may not be present when measured in the laboratory. We know that tension in the muscles of the abdomen, lower back, and pelvis can impede action of the diaphragm in breathing. In natural breathing, the diaphragm moves down toward the lower abdomen, thus producing a partial vacuum in the lung, acting as a passive "balloon" and filling with air when the diaphragm moves down. However, muscle tension in the lower torso can impede movement of the diaphragm. When this happens, "accessory" muscles in the chest and shoulders must be used to create a vacuum in the lung during inhalation. Not only does this increase the work of breathing and general muscle tension, but also, because the skeletal muscles are part of the sympathetic nervous system, the excess muscle tension in the trunk of the body from tension in the lower trunk and compensatory muscular activity in the upper trunk may help a positive feedback loop cascade that increases general sympathetic arousal. In a vicious cycle, increased sympathetic arousal can increase ventilation and the level of hypocapnia that can be promoted by thoracic breathing.

Sighing

We all sigh every few minutes. Several studies have found that sighing may be necessary for proper respiratory regulation (Ramirez, 2014; Vlemincx et al., 2013; Vlemincx, Van Diest, Lehrer, Aubert, & Van den Bergh, 2010). Vlemincx and colleagues found that usually there is a high autocorrelation looking at each breath time compared with the immediately previous one. However, over time this correlation decreases, to the point where the pattern approaches randomness. This appears to trigger a sigh, after which the autocorrelation is restored (Vlemincx et al., 2013; Vlemincx et al., 2010). Perhaps, as in heart rate variability (HRV), the autocorrelation represents the operation of various negative feedback loops controlling the period of breathing. It is known that, in many oscillatory feedback systems, a completely constant oscillation, such as may occur during paced breathing, may deprive the system of information that may occur at other frequencies. Perhaps the sigh provides the necessary periodic variability for respiratory regulation systems to operate efficiently. It also may help reinflate alveoli where air does not sufficiently reach them in usual tidal breathing.

Sighing also contributes to emotional control (Vlemincx, Meulders, & Abelson, 2017; Vlemincx, Van Diest, & Van den Bergh, 2016). Since sighing is often accompanied by a long slow outbreath, it is possible that sighing also may occur as a modulatory maneuver to decrease anxiety. During exhalation, the vagus nerve produces a decrease in heart rate, with general parasympathetic stimulation. We often are told to "take a deep breath" in order to reduce stress. However, a sigh also increases ventilation and may lead to hyperventilation. Increases in sighing occur with sympathetic arousal (Zanella et al., 2014), where the body anticipates a need for increased oxygen intake, and in anxiety disorders (Roth, 2005), in which hyperventilation often occurs.

CONCLUSION

In approaching this volume, we suggest that readers keep in mind the complexity of factors contributing to strain, vulnerability, hardiness, and resilience. Some may be constitutional. Some may result from early upbringing experiences that may make people more or less reactive to various stressors. Buffering factors such as wealth and socioeconomic status (Jewell, Luecken, Gress-Smith, Crnic, & Gonzales, 2015; Johnson, Cavallaro, & Leon, 2017), family and social support (Gleeson, Hsieh, & Cryer-Coupet, 2016; Gradus, Smith, & Vogt, 2015; Leshem, Haj-Yahia, & Guterman, 2016; Levens, Elrahal, & Sagui, 2016; Mansour & Tremblay, 2016), protection from social and natural disasters (Lai, Lewis, Livings, La Greca, & Esnard, 2017; Lee et al., 2017; Raveis, VanDevanter, Kovner, & Gershon, 2017; Rosellini, Dussaillant, Zubizarreta, Kessler, & Rose, 2018), and social skill (Chua & Pachana, 2016; Cote et al., 2017; Patnaik, 2014; Rosen & Perrewé, 2017; Treadway, Campion, & Williams, 2017; Zhang, Liu, Jiang, Wu, & Tian, 2014) all play important roles. However, stress is a universal experience, and almost everyone experiences some symptoms, disabilities, or body dysfunctions because of it at some point in life. Therefore, the methods described here may have some usefulness for everyone.

This book is about ways to improve hardiness, prevent and control dysregulation, and improve allostatic capacity. The various methods described here each work on specific aspects of regulatory systems. In a way, all methods of psychotherapy, health promotion, diet, medical intervention, habit control, and so forth have this aim. Although exposure to certain amounts of stress is part of the human condition and may be necessary to tune various allostatic reflexes, excessive stress causes dysregulation. Here we focus on particular empirically validated physical, psychophysiological, and cognitive interventions that prevent and treat dysregulation. Although the various chapters refer to particular outcomes that have received empirical study, the reader should keep in mind that all body and psychological systems are interrelated and affect each other. Resilience and hardiness are strengthened by practicing effective stress management methods. This book describes the foremost empirically tested stress management methods now in use.

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