Psychologists, particularly health psychologists, have long been interested in mind-body phenomena (e.g., Fodor, 1981). How do thoughts, feelings, and behaviors influence our physical health and well-being? How does illness influence our beliefs and attitudes? The emerging field of health neuroscience continues in this tradition, while further emphasizing the role of the brain and its reciprocal influences on physical health and illness (Erickson, Creswell, Verstynen, & Gianaros, 2014). As illustrated in Figure 34.1, health neuroscience intersects with the fields of psychology, medicine, and neuroscience, uniting the efforts of behavioral and biological scientists and practitioners. Subsequent sections of this chapter highlight promising research across a variety of topics of study in health neuroscience, ranging from stress and coping, to health behaviors and health behavior change, to specific conditions (metabolic syndrome). Finally, we consider behavioral applications and interventions in health neuroscience and conclude with suggestions for future research are offered.

To describe the typically disparate areas of neuroscience, psychology, and medicine, Pariante (2016) introduced the phrase “brain-mind-body trichotomy.” According to the trichotomy, whereas the brain is the focus of neuroscience, the mind is under the purview of psychology, and the peripheral body is left to medicine. Health neuroscience disposes of such disciplinary boundaries. Indeed, it has been argued that the mind is inseparable from the brain, and that it makes no sense to try to separate the “biological” from the “psychological” in understanding human behavior (Sapolsky, 2017).

To understand the new and hybrid field, it is informative to compare health neuroscience to its closest academic relatives. Relative to most subdisciplines of psychology, such as cognitive, social, or clinical psychology, health neuroscience has a greater focus on physical health. Clinical or cognitive psychology, in contrast, are geared toward psychological health, or other non-health-specific mental processes. In comparison to health psychology more broadly, health neuroscience is more brain-focused. Whereas health psychologists may be more interested in linking “mind” processes, such as emotions and thoughts, to health parameters, health neuroscientists assess or intervene upon the physical brain more directly. In health neuroscience research, the brain is typically considered to be either the central underlying mechanism of psychological and health processes (top-down), the key target of physical health states (bottom-up), or both (Erickson et al., 2014). Regardless of whether one takes a top-down or bottom-up approach, the fundamental assumption of health neuroscience is that there is added value by increased focus on the brain and by linking the brain to the mind and body. For instance, whereas health psychologists may study how the experience of
specific emotional states are related to inflammatory states, a health neuroscientists may also study activity of the associated brain regions (e.g., coupling between the amygdala and the dorsomedial prefrontal cortex).

Multiple factors can be credited for contributing to the emergence and rise of health neuroscience. Perhaps most obvious is the recent and rapid development of powerful tools to measure and manipulate the central nervous system of humans, such as functional magnetic resonance imaging (fMRI), positron emission tomography (PET), and transcranial magnetic stimulation (TMS). In brief, fMRI allows researchers to detect blood oxygen level-dependent (BOLD) changes in the brain to quantify brain activity in response to various stimuli. For example, fMRI techniques have been used to demonstrate similarities in activity of the anterior cingulate cortex in response to physical and social pain (i.e., rejection; Eisenberger, Lieberman, & Williams, 2003). PET techniques use radioactive tracers to follow the flow of substances of interest (e.g., neurotransmitters) through the brain. In one recent study, researchers demonstrated a link between childhood adversity and increased striatal dopamine function in adulthood (Egerton et al., 2016). Lastly, TMS methods deliver electrical stimulation to excite (or inhibit) brain regions of interest, and some studies have shown preliminary efficacy of repetitive TMS to treat conditions of stress (e.g., Kim, Kim, Kim, & Han, 2016).

Techniques such as fMRI, PET, and TMS have become increasingly powerful and accessible to behavioral health researchers attempting to link brain structure and activity to psychological processes and physical health. Alongside the development of technologies to probe the brain has been the rise of rigorous methods for analyzing and interpreting the biosignal data (e.g., neuroimaging data from fMRI) necessary for processing and understanding the large and complex data acquired by health neuroscience methods, such as computational modeling and multilevel modeling which allow for the simulation and statistical analysis of multivariate and interdependent data. Furthermore, the 2013 launch of the Brain Research through Advancing Innovative Neurotechnologies (BRAIN) Initiative propelled new opportunities for studying the brain and furthering our understanding of its role in health and disease (Insel, Landis, & Collins, 2013). Led by the National Institutes of Health, with partners from across the world, a primary goal of the BRAIN Initiative is “to understand the circuits and patterns of neural activity that give rise to mental experience and behavior” (BRAIN Working Group, 2014, p. 12).

Although much of the research activity funded by the BRAIN Initiative is still-in progress or yet to be awarded, a variety of published reports from the extant literature well illustrate the scope of current health neuroscience research. Health neuroscience topics of study complement traditional areas of emphasis in health psychology, albeit with greater emphasis on the brain.
Health neuroscience represents an untamed frontier for traditional health psychology topics like stress to be examined anew. Initial research in stress shows the promise of a “brain-centered” approach that considers bidirectional relationships between stress, health, and brain. The first piece of this proposed model (i.e., stress affects physiology and health) has been well documented for decades across types of stress, health outcomes, physiological systems, and cultures (Cohen, Gianaros, & Manuck, 2016). Where health neuroscience makes meaningful scientific contributions is through the exploration of the bidirectional relationship between stress and the stress response and brain structure and function.

One traditional health psychology method for understanding the effects of stress on health is through documenting individuals’ physiological patterns in response to controlled laboratory stressors. These patterns can in turn be used in epidemiological health studies to assess long-term health of individuals that have particular stress response patterns. For example, heightened cardiovascular reactivity, such as greater stress-induced increases in blood pressure, have been associated with greater likelihood of developing cardiovascular disease in multiple studies (Chida & Steptoe, 2010). The next questions to answer become why do people over-react physiologically to stressors? Is it because the heightened reactors appraise the stressors as more threatening? Is it because visceral regulation circuits in the brain “overestimate” the physiological response needed to address the stressor, regardless of appraisal? Early brain-imaging studies of cardiovascular stress reactivity indicate that both cognitive appraisals and visceral regulation systems in the brain jointly influence each other to confer cardiovascular disease risk through altered stress responding (Ginty, Kraynak, Fisher, & Gianaros, 2017). This line of health neuroscience inquiry is important for understanding what is driving an individual to “over-react” to stress and improving psychological and medical interventions.

Just as the brain has a regulating effect on the physiological stress response, the physiological stress response affects the brain (McEwen, Nasca, & Gray, 2016). For example, the hypothalamic-pituitary-adrenal (HPA) axis has a negative feedback loop such that cortisol binds to receptors on the hippocampus to end its additional release in a stressful situation. High levels of cortisol and alterations in other hormones are often associated with reductions in the volume of the hippocampus and other changes to the central nervous system (Pruessner et al., 2010). Similarly, increases in circulating inflammatory molecules often follow stressor exposure (Marsland, Walsh, Lockwood, & John-Henderson, 2017). Broadly, inflammation in the blood stream may lead to inflammation in the brain (neuroinflammation), which may affect brain structure and function (Kim & Won, 2017). Neuroinflammation is associated with decreased neurogenesis in the hippocampus and smaller hippocampal volume along with greater dorsal anterior cingulate cortex and anterior insula activity (McEwen et al., 2016), which are key for negative affect (Slavich, Way, Eisenberger, & Taylor, 2010). Thus, there is evidence for a potentially reinforcing pattern of distress and inflammation.

Specific to stress reactivity, work by Muscatell and colleagues (2015) provides more direct evidence for the relationship between stress appraisals and inflammation. Greater inflammatory responses to a laboratory-based social stressor were associated with greater amygdala activity and increased linkage between the amygdala and dorsomedial prefrontal cortex, a brain circuit that amplifies negative emotions. Interestingly, some studies have found more fine-grained relationships between stress reactivity and signals from the body to the brain. For example, fear perceptions seem to be in part regulated differently at different phases in the heartbeat cycle, with processing of frightening stimuli enhanced during systole, or heart contraction (Garfinkel & Critchley, 2016). This line of work indicates demonstrates the importance of interoceptive signals in stress appraisals.
To alleviate the stress response, or to cope with stressors, one may engage in various thoughts and actions, such as emotion regulation. Emotion regulation refers to the process an individual uses to influence which emotions one has, when these emotions are expressed, and for how long they are experienced (Gross, 1998). Emotion regulation is implementation of a strategy to alter the trajectory of a given emotion. Emotion regulation capacity varies significantly across individuals and is notably entangled with psychopathology. A recent meta-analysis by Morawetz, Bode, Derntl, and Heekeren (2016) examined the neural mechanisms of emotion regulation and found, regardless of strategy, emotion regulation involves a core network consisting of the left ventrolateral prefrontal cortex, bilateral insula, and left supplementary motor area. Further, the strength of neural pathways between the amygdala and prefrontal cortex predicted successful emotion regulation (Banks, Eddy, Angstadt, Nathan, & Phan, 2007). Taken together, this work illustrates how health neuroscience research can link individual differences in brain function with subsequent psychological processes that contribute to maladaptive stress responding and other negative health outcomes.

One form of emotion regulation relevant to stress, coping, and health is rumination, a mode of responding to distress that involves repetitively and passively focusing on symptoms of distress and on causes and consequences of these symptoms (Nolen-Hoeksema, Wisco, & Lyubomirsky, 2008). The experience of rumination is usually associated with negative emotion and can be precipitated by stress. In turn, rumination (relative to distraction) can exacerbate acute cortisol and inflammatory responses to psychosocial stress (Zoccola, Figueroa, Rabideau, Woody, & Benencia, 2014). Whereas clinical psychologists may focus on modifying ruminative thinking through psychotherapy, health neuroscience examines brain function and structures that lead to and maintain rumination, as well as the consequences of such thought processes.

Hamilton, Farmer, Fogelman, and Gotlib (2015) synthesized existing neuroscience data to identify the neural substrates of depressive rumination and concluded that increased functional connectivity between the default mode network (DMN) and subgenual prefrontal cortex gives rise to rumination. That is, higher activation in the DMN was associated with higher levels of maladaptive rumination. Moreover, rumination has been associated with reductions in gray matter volume and resting state activity (Kühn, Vanderhasselt, De Raedt, & Gallinat, 2012) as well as increased amygdala reactivity (Mandell, Siegle, Shut, Feldmiller, & Thase, 2014). The work of Denny, Inhoff, Zerubavel, Davachi, and Ochsner (2015) serves as an example of dissolving the “brain-mind-body trichotomy” in health neuroscience research. Using biologically based research (i.e., neural markers of emotional response), the authors demonstrated that cognitive reappraisal training (i.e., a mind phenomenon) attenuated amygdala response to negative images (i.e., a brain phenomenon). By illustrating the impact that the therapeutic intervention can have on changing automatic top-down processes, which may lead to reducing the negative impact of rumination on brain structure and function as well as other health processes (i.e., body phenomena; for review, see Sansone & Sansone, 2012), this line of research illustrates how health neuroscience research can overcome the “brain-mind-body” trichotomy.

Another prominent research focus of health neuroscience is on health behaviors, health behavior change, and the associated brain structures and functions. Although health psychologists have long played a key role in the successful efforts to identify biopsychosocial determinants of health behavior and health behavior modification (e.g., genes, attitudes, cognitions, personality, learning, and sociodemographic factors), the underlying neurobiological processes remain to be elucidated. Such knowledge is not only important for comprehending relevant phenomena (e.g., pain, sleep, addiction), but it is also crucial for better understanding motivation and decision-making processes, which...
is essential for increasing positive health behaviors (e.g., medical screening, vaccination) and decreasing or eliminating negative ones (e.g., smoking, substance abuse).

With respect to addiction, a variety of imaging studies indicate that impairments in dopamine-modulated brain circuits, including those linked to reward, motivation, executive function, and memory, may confer vulnerability (Volkow, Wang, Tomasi, & Baler, 2013). For example, in a study of smokers interested in quitting, Versace and colleagues (2014) found that those who had lower brain reactivity in response to pleasant stimuli compared to cigarette-related cues prior to their quit attempt were less likely to be abstinent six months later. Of note, addiction shares neurobiological overlap with obesity (Volkow et al., 2013). Like the smoking cessation study by Versace and colleagues (2014), other researchers have found that greater brain activity in the nucleus accumbens (a dopaminergic reward system hub) in response to food stimuli, predicted subsequent weight gain in first year female college students (Demos, Heatherton, & Kelley, 2012). Taken together, this line of research may inform the development of more effective strategies for the prevention and treatment of substance-use and eating disorders that reduce the rewarding aspects of harmful substances or increase the rewarding aspects of positive alternatives (Volkow et al., 2013).

Specific Conditions: Metabolic Syndrome

Health neuroscience research on specific conditions aims to incorporate methodologies across disciplines to further elucidate the brain-related causes and consequences of these conditions. One condition of interest is metabolic syndrome (MetS), a constellation of physiological, biochemical, clinical, and metabolic factors that increase the risk for type 2 diabetes, cardiovascular disease, and all-cause mortality (Ford, 2005; see Chapter 31 for a comprehensive review). MetS is characterized by high blood pressure, insulin resistance, elevated triglycerides, reduced high-density lipoprotein cholesterol, and increased abdominal fat. Siervo, Harrison, Jagger, Robinson, and Stephan (2014) conducted a systematic review of MetS and noted insulin resistance is a core pathogenetic feature of MetS and may be linked to increased oxidative stress, low grade inflammation, and endothelial dysfunction. Moreover, the chronic inflammation characteristics of MetS may lead to neuroinflammation, which in turn may underlie the rapid global cognitive decline of individuals with MetS (Viscogliosi et al., 2017). Health neuroscience research shows that the hippocampus is particularly vulnerable to chronic stress and vascular dysfunction, both of which are linked to MetS. For instance, Zhou and colleagues (2010) found that older individuals with diabetes had impairments in episodic memory and displayed reduced functional connectivity between the hippocampus and other brain regions compared to healthy controls. Given that MetS and diabetes have correspondent symptomatology, similar brain regions may be affected.

Health neuroscientists also seek to understand the brain’s role in the development of MetS. For example, individuals with a comorbid psychotic disorder are at increased risk for MetS, which is thought to be related to a dysfunctional oxytocin system in both disorders (Quintana et al., 2016). Despite this and other genetic risk factors, the most effective preventive measures for MetS include behavioral modifications in diet and increased exercise. In a study with rats, Mukwevho and Joseph (2014) found that exercise activated a protein kinase that reduced fatty acids associated with increased risk for MetS. Overall, continued research on risk factors and underlying etiology of MetS may lead to a better understanding of these changes in brain structure and function.

Applications and Interventions

Mindfulness-Based Stress Reduction and the Brain

In recent decades, mindfulness has entered the Western world and has quickly become a major area of neuroscience research. In many ways, mindfulness meditation is the antithesis of rumination in
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that mindfulness involves an intentional disengagement from wandering thoughts to “paying attention in a particular way: on purpose, in the present moment, and non-judgmentally” (Kabat-Zinn, 1990). Mindfulness-Based Stress Reduction (MBSR) is a multimodal treatment aimed at reducing stress through mindfulness strategies. MBSR does in fact significantly decrease rumination (Michalak, Holz, & Teismann, 2011), but beyond symptom reduction, mindfulness is associated with changes in brain structures, enhanced cognitive abilities, improved immune function and perceptual discrimination, and increased prosocial behaviors (Fox et al., 2014).

Mindfulness has been shown to be effective in relieving symptoms related to neurogenic inflammation and promoting an appropriate HPA axis response (Rosenkranz et al., 2013) as well as reducing inflammation as indexed by the proinflammatory cytokine, interleukin-6 (Creswell et al., 2016). In one study, individuals taught mindfulness-based reappraisal strategies more strongly recruited prefrontal cortex regions during the expectation of negative stimuli compared to those with cognitive reappraisal training (Opialla et al., 2015). Similarly, those with mindfulness training demonstrated more efficient emotional and blood pressure recovery after the experience of negative emotions in a separate study (Crosswell et al., 2017). Furthermore, brief mindfulness meditation training in another study strengthened functional connectivity between brain regions associated with executive function (Taren et al., 2017).

A meta-analysis by Fox and colleagues (2014) reveals convergent findings of specific brain regions implicated in the practice of mindfulness (e.g., insular cortex, anterior cingulate cortex, hippocampus). In general, brain regions that are linked to interoceptive behavior, emotion regulation, and attentional control are consistently involved with mindfulness. Given that the mechanisms of such neuroplastic changes are yet to be fully elucidated, there is a need for research aimed at increasing the understanding of how individual differences in brain structures and function play a role in the efficacy and potency of mindfulness practices.

Physical Exercise and the Brain

Although the beneficial physical and mental health effects of exercise are well-established and wide-reaching (see Chapter 8), until recently it has been less clear what role the brain may play in achieving such benefits. As shown by Erickson and colleagues’ (2011) seminal study, a year-long moderate aerobic exercise intervention (relative to a stretching control) increased hippocampal volume by 2% and improved spatial memory in a sample of older adults. These findings are particularly noteworthy as hippocampal volume typically decreases with aging. The results also showed that among those in the exercise group, changes in brain-derived neurotrophic factor (BDNF), a protein known to facilitate growth and differentiation of neurons, predicted greater volume increases in the hippocampus. Moreover, increases in hippocampal volumes mediated the memory improvements. Other lines of research have also shown that regular and single episodes of exercise can both enhance BDNF levels, which can also improve cognition and mood (for meta-analytic review, see Szuhany, Bugatti, & Otto, 2015). Taken together, these studies help to elucidate the neurochemical and structural pathways through which physical exercise may lead to mental health benefits.

Conclusions

The research reviewed in this chapter highlights the promise of health neuroscience to harness the power of advanced neuroimaging technology and to transcend traditional disciplinary boundaries to answer important question regarding the brain, mind, and body. With the increased emphasis on the brain and the integration of theory and analytic of multiple disciplines, the emerging field of health neuroscience has the potential to enhance existing theories and methods that are bound within various biomedical and behavioral specialties. As with any interdisciplinary training and research
endeavor, however, the field of health neuroscience has its share of challenges. Just as health neuroscience processes are complex, so is the assessment of the associated components and functions (e.g., brain structures, molecules, and processes). Accordingly, extensive interdisciplinary and multidisciplinary training in relevant systems, theory, and measurement is necessary to successfully implement health neuroscience research.

A major limitation found across multiple health neuroscience studies is the reliance upon cross-sectional designs. Although longitudinal health neuroscience studies can be logistically difficult and expensive (particularly because of high neuroimaging costs), they would provide significant insight in the causality of the conclusions drawn thus far. Furthermore, more attention should be paid to understanding brain-mind-body phenomenon throughout the lifespan, across the illness–wellness continuum, and for multiple cultures and ethnicities. Many studies that fall within the domain of health neuroscience research utilize healthy samples, excluding participants with neurological or mental or physical health disorders. This is perhaps most notable among emotion regulation research. This is problematic given that individuals who may exhibit the greatest deficits in emotion regulation may be psychiatrically compromised. Thus, future research should examine the differences between emotion regulation skills and brain function in those with and without various mental health conditions. Similarly, to the extent to which we want to understand how brain-mind-body processes generalize from healthy young adults recruited from university and medical centers to other populations, it will be important to focus on more diverse populations in future research. Fortunately, rapid technological advances in neuroimaging and stimulation continue; as technology develops and these techniques become more affordable, hopefully we will see increased use of brain assessments in larger and more diverse longitudinal designs. Currently most brain-imaging studies rely on small sample sizes, precluding direct tests of sex, age, and cultural differences. However, work in related fields suggest that brain morphology and physiology may vary along these dimensions (e.g., DeCarli et al., 2005; Moriguchi et al., 2005). As such, it will be essential for future health neuroscience research to address potential sex, age, and ethnicity differences. Given what we are already learning about the interrelationships between the brain, mind, and body, continued health neuroscience research and application is sure to be fruitful for scientific advances in behavioral and biomedical sciences and public health.

References


