An Introduction to Cultural Neurobiology: Evidence from Physiological Stress Systems

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Changing immigration and demographic patterns have led to the emergence of increasingly diverse and multicultural global communities. In the United States (US), census projections estimate that "ethnic minorities" will collectively become the majority group within the next 20 years (Colby & Ortman, 2014). For example, individuals of Latino/Hispanic descent now comprise 17% of the nation's population and are expected to account for almost 30% by 2060. There has also been steady growth in the number of biracial and multiracial individuals in the US (Colby & Ortman, 2014). This increasing racial/ethnic diversity precipitates increasing interpersonal and social interactions across multiple cultural traditions within families, neighborhoods, schools, and workplaces. Research in the field of psychobiology has long considered the implications of interpersonal and social interactions for stress-sensitive biological processes but has been traditionally slow to recognize the role of culture. Psychobiological researchers, however, are increasingly beginning to examine racial/ethnic and cultural processes, and researchers focusing on culture are beginning to incorporate psychobiological and neurobiological measures. In the current chapter, we provide a broad overview of the newly emerging field of cultural neurobiology.

Although definitions of "culture" may vary, most acknowledge that culture comprises values, traditions, and beliefs that influence the behaviors of a particular social group (American Psychological Association, 2003; Rogoff, 2003). Researchers from a variety of disciplines (e.g., psychology, sociology, anthropology) have garnered a wealth of knowledge through

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the scientific study of culture and its influences on cognition, emotion, and behavior (Cooper & Denner, 1998), but less research has focused on the interplay between culture and biology (Causadias, 2013). Historically, culture has been considered a "macro" construct transmitted through the action of broad social and contextual influences on individuals within particular communities, whereas biology has been considered an "unchangeable" individual quality that is static over time (Rogoff, 2003). As a result of this theoretical distance between cultural and biological processes, empirical research on relations between them has remained relatively underdeveloped (Causadias, Telzer, & Lee, 2017). However, accumulating theory and evidence have emphasized the changeability of biological processes and their sensitivity to social and cultural contexts (Adam, Klimes-Dougan, & Gunnar, 2007; Sterling, 2004). Indeed, culture and biology dynamically interact across multiple time frames (e.g., Li, 2003): from moment to moment as individuals react to acute experiences (Smart Richman, Pek, Pascoe, & Bauer, 2010), from day to day as individuals adapt to varying social demands (Sladek & Doane, 2015), over years as individuals develop in changing sociocultural contexts (Adam et al., 2015), and both ontogenetically and intergenerationally as culture and biology are transmitted through shared environments and genetic and epigenetic pathways (D'Anna-Hernandez et al., 2012; see Causadias, Telzer, & Gonzales, chapter 1 in this volume).

We propose that the term *cultural neurobiology* should be used to encompass the transactions among cultural processes and central and peripheral aspects of neurobiology across the said multiple timeframes. We present a review of the literature supporting the emerging field of cultural neurobiology, and focus on literature that has examined transactions between culture and stress-sensitive neurobiological systems, including the autonomic nervous system (ANS), the hypothalamic-pituitary-adrenal (HPA) axis and immune mechanisms, for several reasons. First, biological indicators of these stress-sensitive systems can be measured outside the laboratory, in naturalistic settings where cultural processes actually occur (Luecken & Gallo, 2008). Second, these systems are commonly hypothesized to be mechanisms that underlie associations between racial/ethnic group membership, race-related psychological stress and health (Myers, 2009), and, more recently, racial/ethnic disparities in academic attainment (Levy, Heissel, Richeson, & Adam, 2016). In addition to focusing on the ANS, the HPA axis, and immune and inflammatory system functioning, we highlight more recent work incorporating multiple stress-sensitive

biological indicators, including allostatic load (e.g., McEwen, 1998) and multisystem approaches (e.g., Bauer, Quas, & Boyce, 2002).

Although researchers have investigated cultural and identity-formation processes among majority-group members (e.g., White, European Americans in the US; Devos & Banaji, 2005; Helms, 1994), most research in the US on the cultural constructs described below in relation to neurobiology has been conducted with racial/ethnic minority or multiracial/-ethnic populations. We do, however, highlight instances when research was conducted with majority-group members. Further, it is worth noting that biological anthropologists (e.g., DeCaro & Worthman, 2008; McDade, Stallings, & Worthman, 2000) have examined interactions between culture and biology in many international contexts (e.g., Flinn & England, 1997; McDade & Worthman, 2004). While a detailed review of international and cross-national studies is beyond the scope of our brief introduction, we acknowledge their influence on the development of cultural neurobiology (e.g., McDade, 2005; Worthman & Costello, 2009).

In this chapter we first review important theoretical perspectives relevant to cultural neurobiology. Next, we briefly describe the function, measurement and health-relevance of the ANS, the HPA axis, immune/inflammatory systems, and allostatic load. We then provide definitions of key cultural constructs from extant literature and present examples of cultural neurobiological studies. In the final section, we highlight adaptive cultural processes and additional biomarkers that hold promise for informing our understanding of transactions between culture and biology.

Culturally Informed Theory

Early endeavors in psychology and related disciplines considered culture simply as a demographic or social grouping factor (i.e., they inferred culture from racial/ethnic categorizations; see García Coll, Akerman, & Cicchetti, 2000). More recently, researchers have argued that culture should be conceptualized as a major influence on individual and group processes rather than as a cursory background variable (García Coll et al., 1996). Here, we follow the lead of our colleagues who consider culture to be both a *context* in which biological processes unfold and a collection of *processes* that change over time. A widely used framework in the study of culture focuses on differences between groups (e.g., citizens of different nations, racial/ethnic groups) as broad constellations of values and

practices termed individualistic (self-focused) or collectivistic (other-focused) (Triandis, 1995). Other researchers have focused on more specific processes that carry particular salience for certain groups with shared sociocultural histories, such as the collectivistic value of familism (feelings of loyalty, reciprocation, and solidarity among family members) among Latinos (Sabogal, Marín, Otero-Sabogal, Marín, & Perez-Stable, 1987). Disciplines such as anthropology use intensive ethnography as well as more quantitative techniques (e.g., cultural consensus modeling) to identify the values, behaviors, traditions, and markers of status important to particular groups living in particular locations at particular points in time, rather than assuming that values are constant and broadly shared among members of an ethnic or racial group (Dressler & Bindon, 2000; Flinn & England, 1997).

García Coll and colleagues (1996) proposed an integrative model of normative development for racial/ethnic-minority youth that considers the unique ecological circumstances of people of color growing up in the US. Based in social stratification theory, the model suggests that observed racial/ethnic differences represent legitimate adaptations to contextual demands embedded within historical and current systems of oppression (e.g., racism, segregation). García Coll et al. (1996) proposed that the experiences of individuals and their families within inhibiting and promoting environments result in *adaptive cultures*, or social systems defined by sets of goals, values, and attitudes that differ from the dominant culture and influence developmental competencies over time. Following this framework, it is important to acknowledge that many minorities are routinely exposed and must respond to daily challenges generated by a racially stratified society (e.g., discrimination, segregated housing).

Given the challenging nature of many everyday experiences for racial/ethnic minorities in the US, much research and theory thus far has focused on racial/ethnic or culturally based stressors that disproportionately affect these groups (American Psychological Association, 2016). However, it is also important to acknowledge that considerable cultural resources and strengths influence transactions between culture and neurobiology. Guided by classic stress and coping theory (Lazarus & Folkman, 1984), we argue that future work must examine the cultural ecology of coping (e.g., Gonzales & Kim, 1997) in cultural neurobiology, including both promotive cultural resources that directly benefit all youth and protective cultural resources that enable some racial/ethnic minorities to achieve positive outcomes despite facing marginalization, discrimination and socioeconomic inequalities (e.g., Causadias, 2013; Neblett, Rivas-Drake, & Umaña-Taylor,

2012). Throughout this chapter, we attempt to highlight such adaptive cultural resources, and their role in neurobiology.

Neurobiological Stress Systems

Here we provide an overview of autonomic nervous system (ANS) activity, the hypothalamic pituitary adrenal (HPA) axis, and immune/inflammatory function, and describe measures of these systems commonly used in behavioral research (for a comprehensive review of physiological stress and methods, see Luecken & Gallo, 2008).

The ANS

The ANS responds rapidly to stressors through a coordination of sympathetic and parasympathetic nervous system activity (SNS and PNS respectively). The SNS response provokes the secretion of epinephrine from the adrenal medulla and norepinephrine from both the adrenal medulla and the sympathetic nerve terminals. Epinephrine, through hormonal effects, and norepinephrine, through a combination of neurotransmitter and hormonal effects, widely influence peripheral organs and tissues (Lovallo & Thomas, 2000). Key effects include increased heart rate and respiratory output, which prepare the body for active responses to physical and psychosocial threats. The polyvagal theory (Porges, 2007) and the neurovisceral integration model (Thayer & Lane, 2000) suggest that the PNS also plays an integral role in the stress response by modulating both SNS and HPA activity. When engaged, the PNS helps to maintain lower heart rate and internal homeostasis, supporting social engagement (Porges, 2007). In contrast, when someone is facing a challenging or stressful situation, PNS activity decreases, releasing the "brakes" this system normally maintains on sympathetic activity and allowing the body to quickly mobilize fight-or-flight responses (Porges, 2007).

Several key measures of ANS activity include cardiovascular reactivity, heart rate variability (HRV) and respiratory sinus arrhythmia (RSA). The most common measures of *cardiovascular reactivity* are blood pressure and heart rate, which have been used in both laboratory and naturalistic settings to measure stress-related changes in cardiovascular function. *Heart rate variability* (HRV) is measured using an electrocardiogram and quantifies changes in beat-to-beat intervals caused by PNS modulation of SNS. Finally, *RSA* is an indicator of HRV that occurs at the frequency of

spontaneous respiration. Researchers have focused on both baseline RSA, measured at rest, and RSA change in response to a particular stressor. High baseline RSA has been theorized to be adaptive, allowing individuals to attend to and engage with their environment quickly (Porges, 2007). Decreases in RSA ("withdrawal") have also been theorized to reflect optimal regulation or vagal flexibility, allowing greater cardiac output and thus more active responses to stress (Muhtadie, Koslov, Akinola, & Mendes, 2015).

The HPA Axis

Through a cascade of hormone events beginning in the brain, activation of the HPA axis results in the release of cortisol into the bloodstream, which helps to provide adaptive behavioral responses during stressful situations. Psychological stressors, particularly those involving lack of control and social evaluation, activate the HPA axis (Dickerson & Kemeny, 2004). While most commonly measured in saliva, cortisol can also be measured in blood, urine and hair. Cortisol peaks in saliva approximately 21-40 minutes after a discrete stressor, but may take up to one hour to return to baseline. Both elevated and blunted cortisol reactivity are associated with poor mental and physical health (Hagan, Roubinov, Mistler, & Luecken, 2014; Phillips, Ginty, & Hughes, 2013).

In addition to its role in stress reactivity, cortisol is released throughout the day in a typical diurnal pattern characterized by relatively high levels at waking, a dramatic increase approximately 30 minutes after waking, then a general decrease across the day with the lowest levels occurring in the late evening hours (Adam & Kumari, 2009; Pruessner et al., 1997). The three metrics most commonly used to index daily HPA axis activity include the cortisol awakening response (CAR, the increase in cortisol levels that typically occurs 30–45 minutes after waking; Clow, Hucklebridge, Stalder, Evans, & Thorn, 2010), the diurnal slope (the linear rate of decline in cortisol levels from waking to bedtime; Adam, Hawkley, Kudielka, & Cacioppo, 2006) and the diurnal area under the curve with respect to ground (AUCg, the total daily output; Pruessner, Kirschbaum, Meinlschmid, & Hellhammer, 2003). Variations in cortisol diurnal patterns have been used as indices of early exposure to adversity or chronic stress (for a review see Ehrlich, Miller, & Chen, 2016), biological susceptibility to environmental influences (Boyce & Ellis, 2005) and exposure to recent acute stressors (for a review see Adam, 2012). Recent research, however, has found that short-term elevations in cortisol provide subsequent reductions in fatigue

and short-term "boosts" in both energy and positive emotional states (Adam et al., 2006; Hoyt, Zeiders, Ehrlich, & Adam, 2016).

Immune Markers

While the ANS and the HPA axis mobilize resources for a response to a challenge or a threat, the immune system provides defense and repair in the face of injury or infection. The immune system identifies cells that are "self" or "other" through innate and acquired immunity. Innate immunity is the body's immediate response to a pathogen: it includes the direct responses of macrophages and natural killer cells, which attack an infection; this attack leads to *inflammation*. Inflammation is the process by which cells of the immune system, primarily cytokines, aggregate at the point of infection. Acquired immunity occurs through a secondary cascade of events that results in the proliferation of lymphocytes; these attack infectious agents (T-cells) and then prepare the body against future infections by creating antibody-mediated immunity (e.g., the ability to recognize the agent in the future). The immune system indicators most often incorporated into behavioral research are measures of cytokines and their related proteins, which play an important role in cell signaling (for a review of stress and the immune response see Glaser & Kiecolt-Glaser, 2014). The most frequently measured inflammatory biomarkers are C-reactive protein, IL-6, IL-12, TNF-α, IFN-γ, and IL1-β.

Much of the immune response is activated by direct connections between the brain and the tissues that produce the immune response. Studies have linked psychosocial stressors and contextual influences with immune system activity and related endocrine processes by using both laboratory and naturalistic paradigms (Glaser & Kiecolt-Glaser, 2005; Kirschbaum & Hellhammer, 1989; McEwen, 1998). Exposure to social stressors in both laboratory and naturalistic settings is associated with elevated inflammatory activity (Dickerson, Gable, Irwin, Aziz, & Kemeny, 2009; Fuligni et al., 2009). There are additional communication pathways in the body between autonomic, HPA, and immune systems (e.g., immune-suppressive or enhancing effects), all of which contribute to illness and disease vulnerability. The HPA and ANS responses to stress can influence immune function either directly, through binding of the hormone to receptors (e.g., glucocorticoid receptors), or indirectly, through suppression or overproduction of cells that send vital signals to cytokines (Glaser & Kiecolt-Glaser, 2005; Padgett & Glaser, 2003; Webster, Tonelli, & Sternberg, 2002).

Allostatic Load and Multisystem Approaches

One approach to studying how psychosocial stressors influence multiple biological systems is to use a quantitative additive indicator – allostatic load (AL), a concept pioneered by McEwen (1998). Under normal circumstances, the body adjusts biological responses to match acute environmental demands, a process called allostasis (McEwen, 1998, 2000; McEwen & Seeman, 1999; Sterling & Eyer, 1988). Under conditions of ongoing stress, however, dysregulation of multiple biological systems may occur as a result of cumulative "wear and tear" (i.e., chronic over- or underactivation). Measures of AL summarize dysregulation across multiple systems, including those responsible for immune, endocrine, metabolic, and cardiovascular function. Measures of AL have been used as outcomes of chronic stress (e.g., Dich, Lange, Head, & Rod, 2015) as well as predictors of disease (e.g., Mattei, Demissie, Falcon, Ordovas, & Tucker, 2010).

Many have suggested that studies should move beyond one-to-one associations between psychosocial constructs and single indicators of biology (Bauer, Quas, & Boyce, 2002; McEwen, 2000; Quas et al., 2014). Biological systems may work independently to inhibit or enhance each other's functions, or together in response to stress (e.g., Laurent, Lucas, Pierce, Goetz, & Granger, 2016). Thus, *multisystem* approaches emphasize the importance of including multiple indicators of interacting biological systems to elucidate connections between psychological experience and physical and mental health and disease.

Evidence of Relations between Culture and Neurobiology

The second aim of this chapter is to introduce research contributions that have already been made to our understanding of cultural neurobiology. Racial/ethnic minorities face more and different stressors from majority group members. For example, in a national US survey (American Psychological Association, 2016), Black, Latino, Asian, and American Indian/Alaska Native adults reported more everyday discrimination than did non-Hispanic White adults, across most examples of unfair treatment (for example, being treated with less respect, not being hired for a job). Extensive research has contrasted the biological profiles of different racial/ethnic groups in the US, showing differences in stress biology, and assuming that such differences are due to varying cultural processes or stress experiences. Such comparisons have mostly shown that racial/ethnic

minorities exhibit altered ANS, HPA and immune function, which reflects the dysregulation of stress-sensitive systems compared with those of non-Hispanic Whites (e.g., Chapman et al., 2009; Cohen et al., 2006; Geronimus, Hicken, Keene, & Bound, 2006; Mozaffarian et al., 2016). However, some studies have not found such differences, and many have struggled to separate out effects unique to racial/ethnic group membership, given the complex overlap between socioeconomic status and race/ethnicity (Kaufman, Cooper, & McGee, 1997). Rather than reviewing research that shows differences purely by racial/ethnic category, we focus on research in which culturally relevant processes have been directly measured and modeled in relation to stress biology, including perceived discrimination, stereotype threat, ethnic and racial identity, acculturation, and family processes (for a discussion of the effects of poverty on neurobiological systems, see Doan & Evans, chapter 11 in this volume).

Perceived Discrimination

One proximal mechanism or experience used to explain *wh*y stress biology may differ between racial/ethnic majority and minority group members is perceived racial/ethnic discrimination (the perception of being treated unfairly due to one's race or ethnicity).[1] These perceptions of discrimination experiences operate at multiple levels, from *systemic racism* or *chronic discrimination* to *microaggressions* (commonplace racial slights and insults; Sue et al., 2007). Meta-analyses suggest that perceived discrimination has significant detrimental effects on physical and mental health, including depression, anxiety, hypertension, obesity, and substance use (Pascoe & Smart Richman, 2009), with recent evidence pointing to the role of neurobiological stress mechanisms (see Ong, Deshpande, & Williams, chapter 12, and Hill & Hoggard, chapter 14, in this volume).

Perceived racial discrimination has been associated with higher blood pressure (Brondolo et al., 2008), lower HRV (Hill et al., 2017), hypertension (Dolezsar, McGrath, Herzig, & Miller, 2014), and increased risk of cardiovascular disease (Lewis, Williams, Tamene, & Clark, 2014). However, some variation based on racial/ethnic group (e.g., Hispanic, Black) and sex (Lewis et al., 2014; Williams, Neighbors, & Jackson, 2003) has been reported, and longitudinal research on cardiovascular function is rare (Brondolo, Rieppi, Kelly, & Gerin, 2003). Cross-sectional studies of ethnic minority and majority (e.g., European-American) populations have also linked perceived discrimination with HPA-axis activity, including flatter diurnal cortisol slopes and greater cortisol reactivity to laboratory and

everyday stressors (Doane & Zeiders, 2014; Smart Richman & Jonassaint, 2008; Zeiders, Hoyt, & Adam, 2014). Further, there is now evidence of *cumulative effects and sensitive-period effects of discrimination* on cortisol regulation. Perceived racial discrimination measured over 20 years was associated with flatter diurnal cortisol slopes in adulthood among both Blacks and Whites, and perceived discrimination in adolescence accounted for most of this association (Adam et al., 2015).

Evidence from experimental, cross-sectional and longitudinal research suggests similar adverse effects of perceived discrimination on immune function, with most studies focusing on IL-6 or C-reactive protein (CRP). For example, everyday discrimination was associated with higher levels of CRP in older African-American adults (Lewis, Aiello, Leurgans, Kelly, & Barnes, 2010). However, effects vary by sex or race/ethnicity. Results from the Multi-Ethnic Study of Atherosclerosis (MESA) study indicated that both everyday and lifetime discrimination were associated with elevated IL-6 in women, but only everyday discrimination was associated with elevations in men, across all ethnic groups (Kershaw et al., 2016). In a different epidemiological sample, Cunningham and colleagues (2012) found that perceived discrimination was negatively associated with CRP levels in Black men and women but positively associated with CRP in White women.

While some cross-sectional studies have identified perceived discrimination as a key pathway between race/ethnicity and composites of AL (e.g., Tomfohr, Pung, & Dimsdale, 2016), to our knowledge only one study has examined *prospective* relations of perceived discrimination with an AL index. In a longitudinal study of African-American youth, Brody and colleagues (2014) found that perceived discrimination during adolescence was associated with increased AL (cortisol, epinephrine, norepinephrine, blood pressure, CRP, and body mass index (BMI)) in young adulthood, but not for those who reported high levels of emotional support from parents and peers. This study identifies the harmful effects of cumulative discrimination experiences over time, while highlighting the importance of culturally relevant protective processes in the prediction of stress biology.

Stereotype Threat

Beyond the stress of perceiving unfair treatment, researchers have focused on the stress associated with unfair expectations, stereotypes or assumptions regarding one's group, a concept called "stereotype threat" (Steele & Aronson, 1995). In situations where known group stereotypes are

activated, such as when racial/ethnic-minority individuals face a testing situation believing that they are expected to perform poorly because of their race, the attentional demands and stress posed by the threat of that stereotype impair performance (Gonzales, Blanton, & Williams, 2002; Jaramillo, Mello, & Worrell, 2016; Spencer, Logel, & Davies, 2016). Stereotype threat also has biological consequences (Levy et al., 2016; Mendes & Jamieson, 2011), having been linked to increases in blood pressure reactivity, cardiovascular reactivity, HRV, sympathetic activation, cortisol levels, and IL-6 levels (John-Henderson, Rheinschmidt, Mendoza-Denton, & Francis, 2014; see Mendes & Jamieson, 2011, for a review). To our knowledge, stereotype threat has not yet been examined in relation to allostatic load. Past neurobiological stereotype-threat studies have focused on acute activation of stress biology in the context of testing or performance situations; whether repeated stereotype threat is sufficiently biologically aversive to represent a chronic stressor that predicts long-term changes in stress biology remains to be examined.

Ethnic and Racial Identity

The multidimensional construct of ethnic and racial identity (ERI) includes the beliefs and attitudes individuals have about their racial/ethnic group memberships as well as the processes by which these beliefs and attitudes develop over time (Umaña-Taylor et al., 2014). The extent to which racial/ethnic minorities have explored, and made a commitment regarding, their identity as members of their racial/ethnic group, and to which they have positive feelings about their racial/ethnic group membership (known as private regard), is generally associated with positive psychological adjustment (Sellers, Copeland-Linder, Martin, & Lewis, 2006; Umaña-Taylor, Yazedjian, & Bámaca-Gómez, 2004). The salience of ERI formation and how it relates to adjustment among majority-group members is less clear (Helms, 1994; Phinney, 1989). Some evidence indicates that ERI is associated with self-esteem to a lesser degree for Whites than for racial/ethnic minorities (Umaña-Taylor et al., 2004). Researchers have theorized that ERI also buffers racial/ethnic minorities from the adverse effects of discrimination on health and well-being (see Brondolo, Brady Ver Halen, Pencille, Beatty, & Contrada, 2009, for a review).

Some empirical evidence indicates that the protective effect of ERI processes operates through stress biology, particularly ANS reactivity. For example, African Americans with higher private regard exhibited lower RSA reactivity after viewing a racism vignette which showed a White

perpetrator than those with lower private regard (Neblett & Roberts, 2013). Higher private regard has also been associated with lower overall cardiac output during race-related stressors (Clark & Gochett, 2006). Other studies have found that greater internalization of Black identity was associated with *elevated* resting systolic blood pressure in the laboratory, *greater* systolic blood pressure reactivity to race-related stressors, and *elevated* ambulatory blood pressure (e.g., Thompson, Kamarck, & Manuck, 2002; Torres & Bowens, 2000). These seemingly contradictory findings might suggest that greater racial/ethnic salience actually heightens (rather than attenuates) stress reactivity, an adaptive result for individuals who must routinely be prepared to contend with race-related stressors (Sellers et al., 2006). Available neurobiological research has focused almost exclusively on the racial identity of Blacks and ANS activity; future work might consider ERI across other racial/ethnic groups and other neurobiological stress systems.

Acculturation

An emerging literature has started to document differences in stress biology among immigrant groups who vary in levels of acculturation, or the process by which individuals engage in and adapt to a new culture (Ferguson, 2013). Immigrants partly construct their environments by selecting the ethnic heritage traditions or values they prefer to maintain from their countries of origin (*enculturation*), while adapting to traditions of the new mainstream culture (*acculturation*). The psychological stress associated with this dual-cultural adaptation process has been called *acculturative* or *enculturative stress* (Gonzales, Germán, & Fabrett, 2012).

Acculturative and enculturative stressors have been linked with alterations to several neurobiological stress systems. A recent meta-analysis found that immigrants' acculturation to the US and to European countries was associated with increases in both systolic and diastolic blood pressure, independently of other known risk factors (e.g., high body mass index; Steffen, Smith, Larson, & Butler, 2006). Evidence from longitudinal multi-ethnic epidemiological samples has also shown that recent immigrants experience the fastest declines in cardiovascular health (Lê-Scherban et al., 2016). In a series of studies of Mexican-American adults, Mangold and colleagues (2010, 2012) found that greater Anglo orientation (adopting mainstream cultural views and practices) was associated with smaller CARs (a pattern linked with chronic fatigue and "burnout"). Other research on Mexican-American women and their infants has

suggested that maternal cortisol during the prenatal and postpartum period may mediate associations between acculturation and adverse infant outcomes (D'Anna-Hernandez et al., 2012; Ruiz, Pickler, Marti, & Jallo, 2013). Similarly, time spent in the US was associated with the absence of a protective cytokine (IL-10), which subsequently predicted the odds of preterm birth in a sample of Mexican-American pregnant women (Wommack et al., 2013).

Finally, studies of Mexican immigrants and their families have shown that cumulative experiences in the US (for example years living in the US, adapting to mainstream culture) were associated with increased AL, including indicators of blood pressure, glucose, cholesterol and immune function (e.g., McClure et al., 2015). Peek and colleagues (2010) found that US-born individuals of Mexican descent had higher AL scores than their counterparts who had been born in Mexico, but this was *not* accounted for by English language use, social integration or cultural assimilation. This finding suggests that it could be the loss of culturally specific protective factors that explains how acculturation gets under the skin to influence neurobiological function.

Family Processes

Cultural neurobiology research with an emphasis on human development has focused much attention on the family (Fuligni & Telzer, 2013) and other close social ties. Research on *familism* among Latinos, *communalism* among African Americans and *filial piety* among Asian Americans has examined whether these society- and family-centric values are associated with adaptive outcomes for children and families (Schwartz et al., 2010). Family values, such as feeling obligated to help family members, may be protective (Schwartz et al., 2010), whereas some family expectations, such as daily assistance behaviors, may be sources of vulnerability (Fuligni et al., 2009). For example, the values of family unity and support generally promote positive outcomes for Mexican-origin youth (Fuligni, Tseng, & Lam, 1999; Suárez-Orozco & Suárez-Orozco, 1995), but youth who feel responsible for helping their families financially may be significantly burdened by providing assistance in a variety of ways (e.g., translating for family members, childcare).

Perceived availability of social support, particularly from family, may buffer individuals from chronic activation of neurobiological stress activity (e.g., Brody et al., 2014). In contrast, providing for family members (e.g., by undertaking caretaking responsibilities) can have direct, adverse

effects on stress biology (Kiecolt-Glaser et al., 2003), or can moderate or exacerbate the negative effects of other risk factors (e.g., chronic family stress; Marin, Chen, Munch, & Miller, 2009). For example, in a sample of African-American adults, greater cultural consonance was associated with lower systolic and diastolic blood pressure when these adults also perceived greater family support (Dressler & Bindon, 2000). Many studies of racial/ethnic-minority and -majority populations have also indicated that perceived availability of social support, particularly from family, buffers against HPA-axis dysregulation, activation of immune pathways, and AL (e.g., Brody et al., 2014; Doane & Zeiders, 2014; Guan et al., 2016; Jewell, Luecken, Gress-Smith, Crnic & Gonzales, 2015; Seeman, Gruenewald, Cohen, Williams, & Matthews, 2014). Other studies have found that family assistance behaviors are associated with a risk of dysregulated neurobiological stress systems (Chiang et al., 2016; Fuligni et al., 2009; see Fuligni & Telzer, 2013 for a review). For example, family assistance behaviors were associated with *higher* levels of immune markers, including sIL-6r and CRP (Fuligni et al., 2009). Interestingly, this association was attenuated among youth with high levels of family obligation values, highlighting the protective role of traditional family-based cultural values.

Conclusions and Future Directions

The following chapters in this part represent exciting extensions of cultural neurobiology research across the various biological systems introduced here. In addition to the pioneering work conducted and reviewed by our colleagues in the following chapters, we offer four categories as central candidates for future work, with an emphasis on *positive or protective cultural processes*: (1) supportive family processes, (2) biculturalism or multiculturalism, (3) cultural experiences and identities in majority groups, and (4) additional neurobiological markers that hold promise for future culturally informed research.

Supportive Family Processes

From various studies that have explored the supportive role of family processes (e.g., Fuligni & Telzer, 2013), it is clear that more family-centered values and greater perceptions of available family support have the potential to promote enhanced neurobiological stress regulation and protect

individuals from the risk of neurobiological dysfunction when they face stressful conditions. Future research is needed to explore more nuance in family processes (particularly if putatively supportive family influences can become sources of risk) and the corresponding effects on neurobiological systems.

Biculturalism or Multiculturalism

Although research has found that maintaining ties to one's traditional ethnic culture is protective, those who are able to interact effectively within both their ethnic-heritage *and* mainstream cultural contexts garner various psychosocial benefits (García Coll et al., 1996; Nguyen & Benet-Martínez, 2012). Future research should consider biculturalism (or multiculturalism) as a potentially promotive or protective cultural process in relation to neurobiological stress systems. Do highly bicultural individuals benefit from enhanced biological regulation under stress, compared to individuals oriented more exclusively towards either their ethnic-heritage culture or mainstream culture?

Cultural Experiences and Identities for Majority-Group Members

As communities become increasingly diverse with respect to race, ethnicity and the intersection of multiple cultural traditions, it will be critical for cultural neurobiology research to consider the values, attitudes, and identities of those with majority status (e.g., White, European Americans in the US). Our review revealed that most research has focused on culture and biology interplay among racial/ethnic minorities. We encourage future cultural neurobiology research to draw from rich conceptual frameworks that have also considered the salience of these processes for those in the racial/ethnic majority. For example, Helms (1994) argued that White, European Americans develop racial identity through a process that requires them to recognize and abandon internalized White privilege and to create a non-racist, self-defining White identity. Some researchers have already started to examine such processes in relation to stress biology, showing that White Americans' concerns about appearing prejudiced were associated with heightened cortisol responses during interracial encounters in a laboratory and alterations in diurnal cortisol rhythms over a year (Trawalter, Adam, Chase-Lansdale, & Richeson, 2012). More work is needed to consider measured cultural processes among majority-group

members that may support the function and regulation of stress-sensitive neurobiological systems.

Additional Biological Markers of Cultural Relevance

This review, to a large extent reflecting the literature, has focused on stress biology. Many positive aspects of culture may not only serve as buffers against the activation of stress biology, but also relate more directly to biological systems that are involved in positive emotion, social affiliation and motivation. For example, hormones such as dehydroepiandosterone (DHEA) are thought to play a role in coping with stress, and oxytocin is thought to play a role in affiliation and attachment. Researchers are now beginning to consider biomarkers of these systems in cultural neurobiology research. For example, researchers are examining interactions between oxytocin polymorphisms and cultural norms regarding support seeking and emotion regulation (Chiao, 2015; Kim et al., 2010). More research is needed on the positive neurobiology of culture.

Conclusions

We are pleased to highlight research that is exploring a new frontier of cultural neurobiology. Researchers who study social and cultural processes may have little incentive to incorporate neurobiological measures into their work. Of course, the opposite is likely to be true as well: researchers who traditionally focus on neurobiology may not be motivated to draw from the conceptual complexity of cultural theory. As we develop this emerging field, it will be increasingly important to bring these disciplines together. It is also essential to move beyond the study of cultural risk factors and stressors to identify cultural strengths, and how they are interwoven with complex biological systems that regulate everyday psychological and social functioning. Doing so will help us better understand the role of biology not only in disease processes, but in the health, well-being, and thriving of individuals from all cultural backgrounds.

Note

1 We use the term "perceived discrimination" to follow empirical research in the fields of psychology and human development. Perceptions of discrimination across many time courses (past, current or anticipatory) activate the physiological stress processes described in this chapter.

References

Adam, E. K. (2012). Emotion–cortisol transactions occur over multiple time scales in development: Implications for research on emotion and the development of emotional disorders. *Monographs of the Society for Research in Child Development*, *77*(2), 17–27. doi:10.1111/j.1540-5834.2012.00657.x

Adam, E. K., Hawkley, L. C., Kudielka, B. M., & Cacioppo, J. T. (2006). Day-to-day dynamics of experience–cortisol associations in a population-based sample of older adults. *Proceedings of the National Academy of Sciences*, *103*(45), 17058–17063. doi:10.1073/pnas.0605053103

Adam, E. K., Heissel, J. A., Zeiders, K. H., Richeson, J. A., Ross, E. C., Ehrlich, K. B., … & Malanchuk, O. (2015). Developmental histories of perceived racial discrimination and diurnal cortisol profiles in adulthood: A 20-year prospective study. *Psychoneuroendocrinology*, *62*, 279–291. doi:10.1016/j.psyneuen.2015.08.018

Adam, E. K., Klimes-Dougan, B., & Gunnar, M. R. (2007). Social regulation of the adrenocortical response to stress in infants, children and adolescents: Implications for psychopathology and education. In D. Coch, G. Dawson & K. Fischer (Eds.), *Human Behavior, Learning, and the Developing Brain: Atypical Development* (pp. 264–304): New York: Guilford Press.

Adam, E. K., & Kumari, M. (2009). Assessing salivary cortisol in large-scale, epidemiological research. *Psychoneuroendocrinology*, *34*(10), 1423–1436. doi:10.1016/j.psyneuen.2009.06.011

American Psychological Association (2003). Guidelines on multicultural education, training, research, practice, and organizational change for psychologists. *American Psychologist*, *58*, 377–402. doi:10.1037/0003-066X.58.5.377

American Psychological Association (2016). *Stress in America: The impact of discrimination*. Stress in America™ Survey. Retrieved from http://www.apa.org/news/press/releases/stress/2015/impact-of-discrimination.pdf (10 April 2017).

Bauer, A., Quas, J., & Boyce, W. (2002). Associations between physiological reactivity and children's behavior: Advantages of a multisystem approach. *Journal of Developmental and Behavioral Pediatrics*, *23*(2), 102–113. doi:10.1097/00004703-200204000-00007

Boyce, W. T., & Ellis, B. J. (2005). Biological sensitivity to context: I. An evolutionary–developmental theory of the origins and functions of stress reactivity. *Development and Psychopathology*, *17*(2), 271–301. doi:10.1017/S0954579405050145

Brody, G. H., Lei, M. K., Chae, D. H., Yu, T., Kogan, S. M., & Beach, S. R. (2014). Perceived discrimination among African American adolescents and allostatic load: A longitudinal analysis with buffering effects. *Child Development*, *85*(3), 989–1002. doi:10.1111/cdev.12213

Brondolo, E., Brady Ver Halen, N., Pencille, M., Beatty, D., & Contrada, R. J. (2009). Coping with racism: A selective review of the literature and a theoretical and methodological critique. *Journal of Behavioral Medicine*, *32*(1), 64–88. doi:10.1007/s10865-008-9193-0

Brondolo, E., Libby, D. J., Denton, E.-g., Thompson, S., Beatty, D. L., Schwartz, J., … Gerin, W. (2008). Racism and ambulatory blood pressure in a community sample. *Psychosomatic Medicine*, *70*(1), 49–56. doi:10.1097/PSY.0b013e31815ff3bd

Brondolo, E., Rieppi, R., Kelly, K. P., & Gerin, W. (2003). Perceived racism and blood pressure: A review of the literature and conceptual and methodological critique. *Annals of Behavioral Medicine*, *25*(1), 55–65. doi:10.1207/S15324796ABM2501_08

Causadias, J. M. (2013). A roadmap for the integration of culture into developmental psychopathology. *Development and Psychopathology*, *25*, 1375–1398. doi:10.1017/S0954579413000679

Causadias, J. M., Telzer, E. H., & Lee, R. M. (2017). Culture and biology interplay: An introduction. *Cultural Diversity and Ethnic Minority Psychology*, *23*(1), 1–4. doi:10.1037/cdp0000121

Chapman, B. P., Khan, A., Harper, M., Stockman, D., Fiscella, K., Walton, J., … & Moynihan, J. (2009). Gender, race/ethnicity, personality, and interleukin-6 in urban primary care patients. *Brain, Behavior, and Immunity*, *23*(5), 636–642. doi:10.1016/j.bbi.2008.12.009

Chiang, J. J., Tsai, K. M., Park, H., Bower, J. E., Almeida, D. M., Dahl, R. E., … & Fuligni, A. J. (2016). Daily family stress and HPA axis functioning during adolescence: The moderating role of sleep. *Psychoneuroendocrinology*, *71*, 43–53. doi:10.1016/j.psyneuen.2016.05.009

Chiao, J. Y. (2015). Current emotion research in cultural neuroscience. *Emotion Review*, *7*(3), 280–293. doi:10.1177/1754073914546389

Clark, R., & Gochett, P. (2006). Interactive effects of perceived racism and coping responses predict a school-based assessment of blood pressure in black youth. *Annals of Behavioral Medicine*, *32*(1), 1–9. doi:10.1207/s15324796abm3201_1

Clow, A., Hucklebridge, F., Stalder, T., Evans, P., & Thorn, L. (2010). The cortisol awakening response: More than a measure of HPA axis function. *Neuroscience and Biobehavioral Reviews*, *35*(1), 97–103. doi:10.1016/j.neubiorev.2009.12.011

Cohen, S., Schwartz, J. E., Epel, E., Kirschbaum, C., Sidney, S., & Seeman, T. (2006). Socioeconomic status, race and diurnal cortisol decline in the coronary artery risk development in young adults (CARDIA) study. *Psychosomatic Medicine*, *68*, 41–50. doi:10.1097/01.psy.0000195967.51768.ea

Colby, S. L., & Ortman, J. M. (2014). Projections of the size and composition of the U.S. population: 2014 to 2060 (Current population reports, P25-1143). US Census Bureau. Retrieved from https://www.census.gov/content/dam/Census/library/publications/2015/demo/p25-1143.pdf (accessed April 10, 2017).

Cooper, C. R., & Denner, J. (1998). Theories linking culture and psychology: Universal and community-specific processes. *Annual Review of Psychology*, *49*, 559–584. doi:10.1146/annurev.psych.49.1.559

Cunningham, T. J., Seeman, T. E., Kawachi, I., Gortmaker, S. L., Jacobs, D. R., Kiefe, C. I., & Berkman, L. F. (2012). Racial/ethnic and gender differences in the association between self-reported experiences of racial/ethnic discrimination and inflammation in the CARDIA cohort of 4 US communities. *Social Science & Medicine*, *75*(5), 922–931. doi:10.1016/j.socscimed.2012.04.027

D'Anna-Hernandez, K. L., Hoffman, M. C., Zerbe, G. O., Coussons-Read, M., Ross, R. G., & Laudenslager, M. L. (2012). Acculturation, maternal cortisol, and birth outcomes in women of Mexican descent. *Psychosomatic Medicine*, *74*(3), 296–304. doi:10.1097/PSY.0b013e318244fbde

DeCaro, J. A., & Worthman, C. M. (2008). Culture and the socialization of child cardiovascular regulation at school entry in the US. *American Journal of Human Biology*, *20*(5), 572–583. doi:10.1002/ajhb.20782

Devos, T., & Banaji, M. R. (2005). American = white? *Journal of Personality and Social Psychology*, *88*(3), 447–466. doi:10.1037/0022-3514.88.3.447

Dich, N., Lange, T., Head, J., & Rod, N. H. (2015). Work stress, caregiving, and allostatic load: Prospective results from the Whitehall II cohort study. *Psychosomatic Medicine*, *77*(5), 539–547. doi:10.1097/PSY.0000000000000191

Dickerson, S. S., Gable, S. L., Irwin, M. R., Aziz, N., & Kemeny, M. E. (2009). Social-evaluative threat and proinflammatory cytokine regulation: An experimental laboratory investigation. *Psychological Science*, *20*, 1237–1244. doi:10.1111/j.1467-9280.2009.02437.x

Dickerson, S. S., & Kemeny, M. E. (2004). Acute stressors and cortisol responses: A theoretical integration and synthesis of laboratory research. *Psychological Bulletin*, *130*, 355–391. doi:10.1037/0033-2909.130.3.355.

Doane, L. D., & Zeiders, K. H. (2014). Contextual moderators of momentary cortisol and negative affect in adolescents' daily lives. *Journal of Adolescent Health*, *54*, 536–542. doi:10.1016/j.jadohealth.2013.10.007.

Dolezsar, C. M., McGrath, J. J., Herzig, A. J., & Miller, S. B. (2014). Perceived racial discrimination and hypertension: A comprehensive systematic review. *Health Psychology*, *33*(1), 20–34. doi:10.1037/a0033718

Dressler, W. W., & Bindon, J. R. (2000). The health consequences of cultural consonance: Cultural dimensions of lifestyle, social support and arterial blood pressure in an African American community. *American Anthropology*, *102*, 244–260. doi:10.1525/aa.2000.102.2.244

Ehrlich, K. B., Miller, G. E., & Chen, E. (2016). Childhood adversity and adult physical health. In D. Cicchetti (Ed.), *Developmental Psychopathology* (3rd ed., pp. 1–42). Hoboken, NJ: John Wiley & Sons.

Ferguson, G. M. (2013). The big difference a small island can make: How Jamaican adolescents are advancing acculturation science. *Child Development Perspectives*, *7*(4), 248–254. doi:10.1111/cdep.12051

Flinn, M. V., & England, B. G. (1997). Social economics of childhood glucocorticoid response and health. *American Journal of Physical Anthropology*, *102*, 33–53. doi:10.1002/(SICI)1096-8644(199701)102:1<33::AID-AJPA4>3.0.CO;2-E

Fuligni, A. J., & Telzer, E. H. (2013). Another way family can get in the head and under the skin: The neurobiology of helping the family. *Child Development Perspectives*, *7*(3), 138–142. doi:10.1111/cdep.12029

Fuligni, A. J., Telzer, E. H., Bower, J., Cole, S. W., Kiang, L., & Irwin, M. R. (2009). A preliminary study of daily interpersonal stress and C-reactive protein levels among adolescents from Latin American and European backgrounds. *Psychosomatic Medicine*, *71*(3), 329–333. doi:10.1097/PSY.0b013e3181921b1f

Fuligni, A. J., Tseng, V., & Lam, M. (1999). Attitudes toward family obligations among American adolescents with Asian, Latin American, and European backgrounds. *Child Development*, *70*(4), 1030–1044. doi:10.1111/1467-8624.00075

García Coll, C., Akerman, A., & Cicchetti, D. (2000). Cultural influences on developmental processes and outcomes: Implications for the study of development and psychopathology. *Development and Psychopathology*, *12*(3), 333–356.

García Coll, C., Lamberty, G., Jenkins, R., McAdoo, H. P., Crnic, K., Wasik, B. H., & Vázquez García, H. (1996). An integrative model for the study of competencies in minority children. *Child Development*, *67*(5), 1891–1914. doi:10.2307/1131600

Geronimus, A. T., Hicken, M., Keene, D., & Bound, J. (2006). "Weathering" and age patterns of allostatic load scores among blacks and whites in the United States. *American Journal of Public Health*, *96*(5), 826–833. doi:10.2105/AJPH.2004.060749

Glaser, R., & Kiecolt-Glaser, J. K. (2005). Stress-induced immune dysfunction: Implications for health. *Nature Reviews Immunology*, *5*, 243–251. doi:10.1038/nri1571

Glaser, R., & Kiecolt-Glaser, J. K. (Eds.). (2014). *Handbook of human stress and immunity*. San Diego, CA: Academic Press.

Gonzales, N. A., Germán, M., & Fabrett, F. C. (2012). US Latino youth. In E. Chang & C. Downey (Eds.), *Handbook of race and development in mental health* (pp. 259–278). New York: Springer.

Gonzales, N. A., & Kim, L. (1997). Stress and coping in an ethnic minority context: Children's cultural ecologies. In S. A. Wolchik & I. N. Sandler (Eds.), *Handbook of children's coping: Linking theory and intervention* (pp. 481–511). New York: Plenum.

Gonzales, P. M., Blanton, H., & Williams, K. J. (2002). The effects of stereotype threat and double-minority status on the test performance of Latino women. *Personality and Social Psychology Bulletin*, *28*(5), 659–670. doi:10.1177/0146167202288010

Guan, S. S. A., Bower, J. E., Almeida, D. M., Cole, S. W., Dahl, R. E., Irwin, M. R., … & Fuligni, A. J. (2016). Parental support buffers the association of depressive symptoms with cortisol and C-reactive protein during adolescence. *Brain, Behavior, and Immunity*, *57*, 134–143. doi:10.1016/j.bbi.2016.03.007

Hagan, M. J., Roubinov, D. S., Mistler, A. K., & Luecken, L. J. (2014). Mental health outcomes in emerging adults exposed to childhood maltreatment: The moderating role of stress reactivity. *Child Maltreatment*, *19*(3–4), 156–167. doi:10.1177/1077559514539753

Helms, J. E. (1994). The conceptualization of racial identity and other "racial" constructs. In E. J. Trickett, R. J. Watts, & D. Birman (Eds.), *Human diversity: Perspectives on people in context* (pp. 285–311). San Francisco, CA: Jossey-Bass.

Hill, L. K., Hoggard, L. S., Richmond, A. L., Gray, D. L., Williams, D. P., & Thayer, J. F. (2017). Examining the associations between perceived discrimination and heart rate variability in African Americans. *Cultural Diversity and Ethnic Minority Psychology*, *23*(1), 5–14. doi:10.1037/cdp0000076

Hoyt, L. T., Zeiders, K. H., Ehrlich, K. B., & Adam, E. K. (2016). Positive upshots of cortisol in everyday life. *Emotion*, *16*(4), 431–435. doi:10.1037/emo0000174

Jaramillo, J., Mello, Z. R., & Worrell, F. C. (2016). Ethnic identity, stereotype threat, and perceived discrimination among Native American adolescents. *Journal of Research on Adolescence*, *26*(4), 769–775. doi:10.1111/jora.12228

Jewell, S. L., Luecken, L. J., Gress-Smith, J., Crnic, K. A., & Gonzales, N. A. (2015). Economic stress and cortisol among postpartum low-income Mexican American women: Buffering influence of family support. *Behavioral Medicine*, *41*(3), 138–144. doi:10.1080/08964289.2015.1024603

John-Henderson, N. A., Rheinschmidt, M. L., Mendoza-Denton, R., & Francis, D. D. (2014). Performance and inflammation outcomes are predicted by different facets of SES under stereotype threat. *Social Psychological and Personality Science*, *5*(3), 301–309. doi:10.1177/1948550613494226

Kaufman, J. S., Cooper, R. S., & McGee, D. L. (1997). Socioeconomic status and health in blacks and whites: The problem of residual confounding and the resiliency of race. *Epidemiology*, *8*, 621–628. doi:10.1097/00001648-199710000-00002

Kershaw, K. N., Lewis, T. T., Diez Roux, A. V., Jenny, N. S., Liu, K., Penedo, F. J., & Carnethon, M. R. (2016). Self-reported experiences of discrimination and inflammation among men and women: The multi-ethnic study of atherosclerosis. *Health Psychology*, *35*(4), 343–350. doi:10.1037/hea0000331

Kiecolt-Glaser, J. K., Preacher, K. J., MacCallum, R. C., Atkinson, C., Malarkey, W. B., & Glaser, R. (2003). Chronic stress and age-related increases in the proinflammatory cytokine IL-6. *Proceedings of the National Academy of Sciences*, *100*(15), 9090–9095. doi:10.1073/pnas.1531903100

Kim, H. S., Sherman, D. K., Sasaki, J. Y., Xu, J., Chu, T. Q., Ryu, C., … Taylor, S. E. (2010). Culture, distress, and oxytocin receptor polymorphism (OXTR) interact to influence emotional support seeking. *Proceedings of the National Academy of Sciences*, *107*(36), 15717–15721. doi:10.1073/pnas.1010830107

Kirschbaum, C., & Hellhammer, D. H. (1989). Salivary cortisol in psycho-biological research: An overview. *Neuropsychobiology*, *22*, 150–169. doi:10.1159/000118611

Laurent, H. K., Lucas, T., Pierce, J., Goetz, S., & Granger, D. A. (2016). Coordination of cortisol response to social evaluative threat with autonomic and inflammatory responses is moderated by stress appraisals and affect. *Biological Psychology*, *118*, 17–24. doi:10.1016/j.biopsycho.2016.04.066

Lazarus, R. S., & Folkman, S. (1984). *Stress, appraisal, and coping*. New York: Springer Publishing Company.

Lê-Scherban, F., Albrecht, S. S., Bertoni, A., Kandula, N., Mehta, N., & Roux, A. V. D. (2016). Immigrant status and cardiovascular risk over time: Results from the Multi-Ethnic Study of Atherosclerosis. *Annals of Epidemiology*, *26*(6), 429–435. doi:10.1016/j.annepidem.2016.04.008

Levy, D. J., Heissel, J., Richeson, J. A., & Adam, E. K. (2016). Psychological and biological responses to race-based social stress as pathways to disparities in educational outcomes. *American Psychologist*, *71*(6), 455–473. doi:10.1037/a0040322

Lewis, T. T., Aiello, A. E., Leurgans, S., Kelly, J., & Barnes, L. L. (2010). Self-reported experiences of everyday discrimination are associated with elevated C-reactive protein levels in older African-American adults. *Brain, Behavior, and Immunity*, *24*(3), 438–443. doi:10.1016/j.bbi.2009.11.011

Lewis, T. T., Williams, D. R., Tamene, M., & Clark, C. R. (2014). Self-reported experiences of discrimination and cardiovascular disease. *Current Cardiovascular Risk Reports*, *8*(1), 1–15. doi:10.1007/s12170-013-0365-2

Li, S. (2003). Biocultural orchestration of developmental plasticity across levels: The interplay of biology and culture in shaping the mind and behavior across the lifespan. *Psychological Bulletin*, *129*(2), 171–194. doi:10.1037/0033-2909.129.2.171

Lovallo, W., & Thomas, T. (2000). Stress hormones in psychophysiological research. In J. Cacioppo, L. Tassinary, & G. Bernston (Eds.), *Handbook of Psychophysiology* (2nd ed., pp. 342–367). Cambridge: Cambridge University Press.

Luecken, L. J., & Gallo, L. C. (Eds.). (2008). *Handbook of physiological research methods in health psychology*. Thousand Oaks, CA: Sage Publications.

Mangold, D., Mintz, J., Javors, M., & Marino, E. (2012). Neuroticism, acculturation and the cortisol awakening response in Mexican American adults. *Hormones and Behavior*, *61*(1), 23–30. doi:10.1016/j.yhbeh.2011.09.009

Mangold, D., Wand, G., Javors, M., & Mintz, J. (2010). Acculturation, childhood trauma and the cortisol awakening response in Mexican-American adults. *Hormones and Behavior*, *58*(4), 637–646. doi:10.1016/j.yhbeh.2010.06.010

Marin, T. J., Chen, E., Munch, J. A., & Miller, G. E. (2009). Double-exposure to acute stress and chronic family stress is associated with immune changes in children with asthma. *Psychosomatic Medicine*, *71*(4), 378–384. doi:10.1097/PSY.0b013e318199dbc3

Mattei, J., Demissie, S., Falcon, L. M., Ordovas, J. M., & Tucker, K. (2010). Allostatic load is associated with chronic conditions in the Boston Puerto Rican Health Study. *Social Science and Medicine*, *70*(12), 1988–1996. doi:10.1016/j.socscimed.2010.02.024

McClure, H. H., Snodgrass, J. J., Martinez, C. R., Jr, Squires, E. C., Jiménez, R. A., Isiordia, L. E., … & Small, J. (2015). Stress, place, and allostatic load among Mexican immigrant farmworkers in Oregon. *Journal of Immigrant and Minority Health*, *17*(5), 1518–1525. doi:10.1007/s10903-014-0066-z

McDade, T. W. (2005). The ecologies of human immune function. *Annual Review of Anthropology*, *34*, 495–521. doi:10.1146/annurev.anthro.34.081804.120348

McDade, T. W., Stallings, J., & Worthman, C. M. (2000). Culture change and stress in Western Samoan youth: Methodological issues in the cross-cultural study of stress and immune function. *American Journal of Human Biology*, *12*, 792–802. doi:10.1002/1520-6300(200011/12)12:6<792::AID-AJHB7>3.0.CO;2-F

McDade, T. W., & Worthman, C. M. (2004). Socialization ambiguity in Samoan adolescents: A model for human development and stress in the context of culture change. *Journal of Research on Adolescence*, *14*(1), 49–72. doi:10.1111/j.1532-7795.2004.01401003.x

McEwen, B. S. (1998). Stress, adaptation, and disease: Allostasis and allostatic load. *Annals of the New York Academy of Sciences*, *840*, 33–44. doi:10.1111/j.1749-6632.1998.tb09546.x

McEwen, B. S. (2000). Allostasis and allostatic load: Implications for neuropsychopharmacology. *Neuropsychopharmacology*, *22*(2), 108–124. doi:10.1016/S0893-133X(99)00129-3

McEwen, B. S., & Seeman, T. (1999). Protective and damaging effects of mediators of stress: Elaborating and testing the concepts of allostasis and allostatic load. *Annals of the New York Academy of Sciences*, *896*(1), 30–47. doi:10.1111/j.1749-6632.1999.tb08103.x

Mendes, W. B., & Jamieson, J. (2011). Embodied stereotype threat: Exploring brain and body mechanisms underlying performance impairments. In M. Inzlicht & T. Schmader (Eds.), *Stereotype threat: Theory, process, and application* (pp. 51–68). New York: Oxford University Press.

Mozaffarian, D., Benjamin, E. J., Go, A. S., Arnett, D. K., Blaha, M. J., Cushman, M., … & Fullerton, H. J. (2016). Executive summary: Heart disease and stroke statistics – 2016 update: A report from the American Heart Association. *Circulation*, *133*(4), 447–454. doi:10.1161/CIR.0000000000000366

Muhtadie, L., Koslov, K., Akinola, M., & Mendes, W. B. (2015). Vagal flexibility: A physiological predictor of social sensitivity. *Journal of Personality and Social Psychology*, *109*, 106–120. doi:10.1037/pspp0000016

Myers, H. F. (2009). Ethnicity- and socio-economic status-related stresses in context: An integrative review and conceptual model. *Journal of Behavioral Medicine*, *32*, 9–19. doi:10.1007/s10865-008-9181-4

Neblett, E. W., Rivas-Drake, D., & Umaña-Taylor, A. J. (2012). The promise of racial and ethnic protective factors in promoting ethnic minority youth development. *Child Development Perspectives*, *6*(3), 295–303. doi:10.1111/j.1750-8606.2012.00239.x

Neblett, E. W., & Roberts, S. O. (2013). Racial identity and autonomic responses to racial discrimination. *Psychophysiology*, *50*(10), 943–953. doi:10.1111/psyp.12087

Nguyen, A.-M. D., & Benet-Martinez, V. (2012). Biculturalism and adjustment: A meta-analysis. *Journal of Cross-Cultural Psychology*, *44*(1), 122–159. doi:10.1177/0022022111435097

Padgett, D. A., & Glaser, R. (2003). How stress influences the immune response. *Trends in Immunology*, *24*(8), 444–448. doi:10.1016/S1471-4906(03)00173-X

Pascoe, E. A., & Smart Richman, L. (2009). Perceived discrimination and health: A meta-analytic review. *Psychological Bulletin*, *135*(4), 531–554. doi:10.1037/a0016059

Peek, M. K., Cutchin, M. P., Salinas, J. J., Sheffield, K. M., Eschbach, K., Stowe, R. P., & Goodwin, J. S. (2010). Allostatic load among non-Hispanic whites, non-Hispanic blacks, and people of Mexican origin: Effects of ethnicity, nativity, and acculturation. *American Journal of Public Health*, *100*(5), 940–946. doi:10.2105/AJPH.2007.129312

Phillips, A. C., Ginty, A. T., & Hughes, B. M. (2013). The other side of the coin: Blunted cardiovascular and cortisol reactivity are associated with negative health outcomes. *International Journal of Psychophysiology*, *90*(1), 1–7. doi:10.1016/j.ijpsycho.2013.02.002

Phinney, J. S. (1989). Stages of ethnic identity development in minority group adolescents. *Journal of Early Adolescence*, *9*(1–2), 34–49. doi:10.1177/0272431689091004

Porges, S. W. (2007). The polyvagal perspective. *Biological Psychology*, *74*(2), 116–143. doi:10.1016/j.biopsycho.2006.06.009

Pruessner, J. C., Kirschbaum, C., Meinlschmid, G., & Hellhammer, D. H. (2003). Two formulas for computation of the area under the curve represent measures of total hormone concentration versus time-dependent

change. *Psychoneuroendocrinology*, *28*(7), 916–931. doi:10.1016/S0306-4530(02)00108-7

Pruessner, J. C., Wolf, O. T., Hellhammer, D. H., Buske-Kirschbaum, A., von Auer, K., Jobst, S., … & Kirschbaum, C. (1997). Free cortisol levels after awakening: A reliable biological marker for the assessment of adrenocortical activity. *Life Sciences*, *61*, 2539–2549. doi:10.1016/S0024-3205(97)01008-4

Quas, J. A., Yim, I. S., Oberlander, T. F., Nordstokke, D., Essex, M. J., Armstrong, J. M., … Boyce, W. T. (2014). The symphonic structure of childhood stress reactivity: Patterns of sympathetic, parasympathetic, and adrenocortical responses to psychological challenge. *Development and Psychopathology*, *26*, 963–982. doi:10.1017/S0954579414000480

Rogoff, B. (2003). *The cultural nature of cognitive development*. New York: Oxford University Press.

Ruiz, R. J., Pickler, R. H., Marti, C. N., & Jallo, N. (2013). Family cohesion, acculturation, maternal cortisol, and preterm birth in Mexican-American women. *International Journal of Women's Health*, *5*, 243–252. doi:10.2147/IJWH.S42268

Sabogal, F., Marín, G., Otero-Sabogal, R., Marín, B. V., & Perez-Stable, E. J. (1987). Hispanic familism and acculturation: What changes and what doesn't? *Hispanic Journal of Behavioral Sciences*, *9*(4), 397–412. doi:10.1177/07399863870094003

Schwartz, S. J., Weisskirch, R. S., Hurley, E. A., Zamboanga, B. L., Park, I. J., Kim, S. Y., … & Greene, A. D. (2010). Communalism, familism, and filial piety: Are they birds of a collectivist feather? *Cultural Diversity and Ethnic Minority Psychology*, *16*(4), 548–560. doi:10.1037/a0021370

Seeman, T. E., Gruenewald, T. L., Cohen, S., Williams, D. R., & Matthews, K. A. (2014). Social relationships and their biological correlates: Coronary Artery Risk Development in Young Adults (CARDIA) study. *Psychoneuroendocrinology*, *43*, 126–138. doi:10.1016/j.psyneuen.2014.02.008

Sellers, R. M., Copeland-Linder, N., Martin, P. P., & Lewis, R. L. (2006). Racial identity matters: The relationship between racial discrimination and psychological functioning in African American adolescents. *Journal of Research on Adolescence*, *16*(2), 187–216.

Sladek, M. R., & Doane, L. D. (2015). Daily diary reports of social connection, objective sleep, and the cortisol awakening response during adolescents' first year of college. *Journal of Youth and Adolescence*, *44*, 298–316. doi:10.1007/s10964-014-0244-2

Smart Richman, L. S., & Jonassaint, C. (2008). The effects of race-related stress on cortisol reactivity in the laboratory: Implications of the Duke lacrosse scandal. *Annals of Behavioral Medicine*, *35*(1), 105–110. doi:10.1007/s12160-007-9013-8

Smart Richman, L., Pek, J., Pascoe, E., & Bauer, D. J. (2010). The effects of perceived discrimination on ambulatory blood pressure and affective responses to interpersonal stress modeled over 24 hours. *Health Psychology*, *29*(4), 403–411. doi:10.1037/a0019045

Spencer, S. J., Logel, C., & Davies, P. G. (2016). Stereotype threat. *Annual Review of Psychology*, *67*(1), 415–437. doi:10.1146/annurev-psych-073115-103235

Steele, C. M., & Aronson, J. (1995). Stereotype threat and the intellectual test performance of African Americans. *Journal of Personality and Social Psychology*, *69*(5), 797–811. doi:10.1037/0022-3514.69.5.797

Steffen, P. R., Smith, T. B., Larson, M., & Butler, L. (2006). Acculturation to Western society as a risk factor for high blood pressure: A meta-analytic review. *Psychosomatic Medicine*, *68*(3), 386–397. doi:10.1097/01.psy.0000221255.48190.32

Sterling, P. (2004). Principles of allostasis: Optimal design, predictive regulation, pathophysiology, and rational therapeutics. In J. Schulkin (Ed.), *Allostasis, homeostasis, and the costs of adaptation* (pp. 17–64). Cambridge: Cambridge University Press.

Sterling, P., & Eyer, J. (1988). Allostasis: A new paradigm to explain arousal pathology. In S. Fisher & J. Reason (Eds.), *Handbook of life stress, cognition and health* (pp. 629–649). New York: Wiley.

Suárez-Orozco, C., & Suárez-Orozco, M. (1995). *Transformations: Immigration, family life, and achievement motivation among Latino adolescents*. Stanford, CA: Stanford University Press.

Sue, D. W., Capodilupo, C. M., Torino, G. C., Bucceri, J. M., Holder, A., Nadal, K. L., & Esquilin, M. (2007). Racial microaggressions in everyday life: Implications for clinical practice. *American Psychologist*, *62*(4), 271–286. doi:10.1037/0003-066X.62.4.271

Thayer, J. F., & Lane, R. D. (2000). A model of neurovisceral integration in emotion regulation and dysregulation. *Journal of Affective Disorders*, *61*(3), 201–216. doi:10.1016/S0165-0327(00)00338-4

Thompson, H. S., Kamarck, T. W., & Manuck, S. B. (2002). The association between racial identity and hypertension in African-American adults: Elevated resting and ambulatory blood pressure as outcomes. *Ethnicity and Disease*, *12*(1), 20–28.

Tomfohr, L. M., Pung, M. A., & Dimsdale, J. E. (2016). Mediators of the relationship between race and allostatic load in African and White Americans. *Health Psychology*, *35*(4), 322–332. doi:10.1037/hea0000251

Torres, A., & Bowens, L. (2000). Correlation between the internalization theme of racial identity attitude survey-B and systolic blood pressure. *Ethnicity and Disease*, *10*(3), 375–383.

Trawalter, S., Adam, E. K., Chase-Lansdale, P. L., & Richeson, J. A. (2012). Concerns about appearing prejudiced get under the skin: Stress responses to interracial contact in the moment and across time. *Journal of Experimental Social Psychology*, *48*, 682–693. doi:10.1016/j.jesp.2011.12.003

Triandis, H. C. (1995). Attributes of individualism and collectivism. In *Individualism & collectivism* (pp. 43–80). Boulder, CO: Westview Press.

Umaña-Taylor, A. J., Quintana, S. M., Lee, R. M., Cross, W. E., Rivas-Drake, D., Schwartz, S. J., … Sellers, R. M. (2014). Ethnic and racial identity during adolescence and into young adulthood: An integrated conceptualization. *Child Development*, *85*(1), 21–39. doi:10.1111/cdev.12196

Umaña-Taylor, A. J., Yazedjian, A., & Bámaca-Gómez, M. Y. (2004). Developing the Ethnic Identity Scale using Eriksonian and social identity perspectives. *Identity*, *4*(1), 9–38. doi:10.1207/S1532706XID0401_2

Webster, J. I., Tonelli, L., & Sternberg, E. M. (2002). Neuroendocrine regulation of immunity. *Annual Review of Immunology*, *20*(1), 125–163. doi:10.1146/annurev.immunol.20.082401.104914

Williams, D. R., Neighbors, H. W., & Jackson, J. S. (2003). Racial/ethnic discrimination and health: Findings from community studies. *American Journal of Public Health*, *93*, 200–208. doi:10.2105/AJPH.93.2.200

Wommack, J. C., Ruiz, R. J., Marti, C. N., Stowe, R. P., Brown, C. E., & Murphey, C. (2013). Interleukin-10 predicts preterm birth in acculturated Hispanics. *Biological Research for Nursing*, *15*(1), 78–85. doi:10.1177/1099800411416225

Worthman, C. M., & Costello, E. J. (2009). Tracking biocultural pathways to health disparities: The use of biomarkers. *Annals of Human Biology*, *36*, 281–297. doi:10.1080/03014460902832934

Zeiders, K. H., Hoyt, L. T., & Adam, E. K. (2014). Associations between self-reported discrimination and diurnal cortisol rhythms among young adults: The moderating role of racial–ethnic minority status. *Psychoneuroendocrinology*, *50*, 280–288. doi:10.1016/j.psyneuen.2014.08.023