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Structural Racism and its Pathways to Asthma and Atopic Dermatitis

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Abstract

Black, Latinx and Indigenous people in the United States experience a disproportionate burden of asthma and atopic dermatitis. The study of these disease disparities has focused on proximal socioenvironmental exposures and on the biomechanistic, including genetic, differences between racial and ethnic groups. While biomedical research in allergy and immunology stands to benefit from the inclusion of diverse study populations, the narrow focus on biologic mechanisms disregards the complexity of interactions across biological and structural factors, including the effects of structural racism. Structural racism is the totality of ways in which society fosters discrimination by creating and reinforcing inequitable systems through intentional policies and practices sanctioned by government and institutions. It is embedded across multiple levels, including the economic, educational, health care and judicial systems, which manifest in inequity in the physical and social environment. In this review, we present a conceptual framework and pull from the literature to demonstrate how structural racism is a root cause of atopic disease disparities, by way of residential segregation, socioeconomic position, and mass incarceration that may lead to aberrations in the innate and adaptive immune response and the augmentation of physiological stress responses, contributing to a disproportionate disease burden for racial and ethnic populations.

Keywords

Racism; Health Disparities; Asthma; Allergic Dermatitis; Atopy

INTRODUCTION

Racial and ethnic health disparities have persisted, and in the case of atopic diseases have worsened(1) despite scientific research dedicated to untangling the contributing biomechanisms and dedicated efforts to address poorly controlled disease(2–4), including the rampant introduction of precision medicine therapy(5,6). Asthma and atopic dermatitis are two of the most common chronic conditions of childhood in the United States

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(US), often persisting into adulthood(7,8). Asthma affects over 5.1 million children and over 20 million adults, corresponding to 7.8% of the US population(7). Approximately 7.3% of adults and 13–15% of children have atopic dermatitis(8–10). Like many chronic health conditions, the burden of atopic diseases disproportionally affects Black and Brown communities(11–17). The persistence of disparities require a shift of the biomedical framework to incorporate root causes, particularly the direct and indirect roles of structural racism(18). Structural racism is both historically rooted and culturally reinforced(19). It is the totality of ways in which society fosters discrimination by creating and reinforcing inequitable systems through intentional policies and practices sanctioned by various levels of government and institutions(19–21). Structural racism is embedded across society, including in our economic, educational, health care and justice systems, manifesting as inequitable distribution of resources(19). This is distinct from interpersonal racism, which is the differential treatment with regards to race, skin color, ethnic origin, or immigration status(22).

While we focus this review on role of structural racism contributing to the disparities within the Black, Latinx, and Indigenous communities(11–14,16,23–25), we recognize that the pervasive effects of structural racism has likely influenced disease outcomes in many – if not all – minoritized communities in the US. For this review, we use the term “Latinx”; while not fully adopted by all of the population, given the topic of the manuscript, we felt it was important to select a term that represents a global movement toward more gender inclusive terms(26). We also recognize that “Latinx” encompass diverse subgroups with unique migration to the US; however, these groups also share cultural and environmental risk factors for atopic diseases that are influenced by structural and societal factors(27). Indigenous populations refer to descendants of the peoples who inhabited the Americans prior to European colonization.

A deeper understanding of the history and the ongoing oppression of Black, Latinx, and Indigenous populations in the US is needed to understand the deep rooted and broad effect of structural racism on health outcomes and, specifically, on asthma and atopic dermatitis. This review examines the direct and indirect pathways in which structural racism may increase disease and worsen morbidity for asthma and atopic dermatitis. In the sections that follow, we provide a conceptual framework of structural racism and mechanisms of how it has manifested in the US, review the racial and ethnic disparities for asthma and atopic dermatitis, summarize the literature examining pathways of structural racism, and conclude with recommendations for future research and efforts that move towards reducing disease disparities.

CONCEPTUAL FRAMEWORK

Racial categories in the US were originally established by European settlers in order to assert power over enslaved African and Indigenous People, who were falsely thought to be innately, intellectually, and morally inferior(19). Over centuries, the concept of race and racial differences has been propagated by the field of medicine with the use of racial taxonomies in research and clinical practice(28). To understand how structural racism contributes to disparities in asthma and atopic dermatitis, we propose the following

conceptual framework (Figure 1) pulling from the work of Williams and Mohammed(29,30), Bailey(19,21), and the World Health Organization's Commission on Social Determinants of Health framework(31). The determinants of health include biology, geographic origin & ancestry, health behavior, and the social context as influenced by societal institutions and structural racism (Figure 1)(29,31). These determinants of health interact and, as is the case with health behaviors, may be influenced heavily by socioenvironmental conditions(32). In Figure 1, the concept of race, and the resulting perceived hierarchy, stems from the perpetuation of structural racism in legal, political, cultural, and economic institutions, which has led to residential segregation, disparate socioeconomic opportunities, and mass incarceration. Structural racism and resulting intermediate pathways create racial inequity which contributes to interpersonal racism. The toll of interpersonal racism and discrimination additionally contribute to inequitable access to health promoting resources (disease prevention) and healthcare access as well as chronic psychosocial stress, while also enhancing the effects of structural racism (Figure 1).

In our framework, structural racism leads to proximal pathways of inequity affecting the physical and social environments. In the physical environment, Black, Latinx, and Indigenous communities are exposed disproportionately to pollutants/environmental hazards, occupational hazards, and poorer housing quality(21,33,34), all factors with a strong evidence-base of association with asthma and atopic dermatitis(25,34–36). In the social environment, Black Latinx, and Indigenous people are more likely to experience financial strain, have less wealth, decreased access to education, live in neighborhoods with higher rates of violence and have a greater number of adverse childhood experiences(33,37–41). Several epidemiologic studies have demonstrated that these proximal pathways are associated with higher physiologic stress burden (Brody 2014, Theal 2012). In addition, discrimination and segregation have been linked to increased inflammation, independent of SEP (Carlson 2017, citation #22 and Simons 2018). Social adversity also produced inflammation in animal models (Cole 2014). Based on the evidence, we hypothesize that these proximal pathways, along with experiences of interpersonal racism, become embedded in the biology through aberrations in the innate and adaptive immune response(42,43). In the sections below, we critically appraise the gaps in our current knowledge and summarize the evidence supporting our framework, which extends from animal to human studies and spans the psychosocial stress to epidemiology research fields.

DISPARITIES IN ASTHMA AND ATOPIC DERMATITIS

In the US, asthma prevalence is substantially higher in Black and Indigenous populations, 10.6% and 10.7%, respectively, compared to 7.7% prevalence within the non-Hispanic White population(7). In addition, Black and Indigenous populations experience higher asthma morbidity with frequent asthma attacks and higher rates of asthma-related health care utilization(11–14). When considered as whole, the prevalence of asthma in Latinx population is lower (6.6%) when compared to most other racial and ethnic groups(7). However, when examined by National subgroup, the prevalence of asthma in Mexican Americans (5.3%) is lower as compared to other subpopulations of Latinx people (8.5%) (7) with Puerto Ricans having the highest lifetime prevalence of asthma(44). Notably, the prevalence of asthma in Mexican Americans is increasing at a greater rate than all

other racial and ethnic groups(11). Mexican American children also have a two-fold increased risk of hospitalization as compared to White children, which is similar to the hospitalization rate of Black children with asthma(11). The lower overall prevalence of asthma in Mexican Americans likely underestimates the impact of acculturation, which reflects an adoption of cultures of the dominant society and captures the duration of time spent in host country(44,45). Higher acculturation has been shown to be associated with higher prevalence of asthma in Mexican Americans(44,46) and other Latinx subgroups(44); similar patterns are seen in several disease outcomes(27,47). Proposed mechanisms include adoption of cultural and behavioral practices that lead to increased disease risk and increased exposure to environmental hazards(27,44). It is important to consider the harmful health effects of being a racialized immigrant in the US(48). Structural racism may uniquely impart its influence on first generation Mexican Americans and other racialized immigrants in the form of economic exploitation, including labor exploitation and curbing access to economic resources and opportunities, and neighborhood disinvestment, contributing to concentration of poverty and increased exposure to environmental hazards(48).

The prevalence of atopic dermatitis is estimated to be 1.7 times higher in Black children as compared to White children, particularly in early childhood(15–17). Black children also have higher risk of persistent and severe disease(16). While the incidence of atopic dermatitis in Latinx children is similar to White children in early childhood, Latinx children have higher risk of persistent and severe disease(9,16). Similar to asthma, the cultural and environmental changes associated with acculturation may play a significant role for Latinx children, as children not born in the US but who have resided in the US for greater than 10 years have higher odds of developing atopic dermatitis as compared to those who recently migrated(49,50). Extrapolating from small population-based studies, the prevalence of atopic dermatitis in the US Indigenous population is an estimated 8–11%(51,52). There are even fewer studies which have examined the severity of atopic dermatitis in Indigenous populations in the US. This is a needed area for research, specifically to identify and address risk factors that may be unique to this community.

Even after accounting for traditionally measured socioeconomic factors, racial and ethnic disparities in asthma and atopic dermatitis persist, contributing to controversy over the reason for this residual difference and used to support theories of biologic determinism(15,53). However, there is sparse evidence supporting that biological differences between racial groups drive disparity in disease prevalence and severity. For example, Abuabara et al. demonstrated that neither genetic ancestry, a polygenetic risk score, nor a genetic skin pigment score explained the prevalence or morbidity disparities in atopic dermatitis between Black and White participants(54). Several studies have identified that loss-of-function (LOF) mutations of the filaggrin (FLG-LOF) gene result in epidermal barrier dysfunction. For people of European ancestry (15,55), FLG1-LOF mutations are associated with more severe atopic dermatitis. Past studies have noted that the four most common FLG-LOF mutations are rare or even absent in individuals of African ancestry(15,55,56). However, with advancement of measurement and availability of whole genome sequencing, more recent reviews have identified the presence of variants across the FLG-LOF gene in individuals of African ancestry, with mutations of this gene also causing more severe disease regardless of mutation type(54–56) These studies highlight why

biomedical research in allergy and immunology stands to benefit from the inclusion of more diverse study populations; however, narrowly focusing on genetic variations disregards the complexity of interactions across biological and structural factors, which together contribute to disease risk. Instead, we argue that the persistent racial and ethnic disparities in asthma and atopic dermatitis likely reflect residual confounding from both unmeasured social and structural determinants, including the downstream effects of structural racism(57). In this work, there is also need to consider the degree to which structural racism is transmitted transgenerationally through epigenetic modification and the consequences of such modifications on health across populations(58–62).

UPSTREAM PATHWAYS OF STRUCTURAL RACISM

Residential Segregation

Soon after the abolishment of slavery, in the Reconstruction Era, segregation policies were established in the form of black codes to ensure continuation of a cheap labor force and, later, as “Jim Crow laws” under the premise of “separate but equal”(63). While zoning laws segregating neighborhoods were viewed unconstitutional by the Supreme Court in 1917, in recovery from the Great Depression, the federal government sanctioned this practice with preferential investment in current and future homeowners through the Home Owners’ Loan Corporation (HOLC)(64). HOLC created maps of at least 239 US cities ranking communities on mortgage-worthiness(21). Inner-city communities with large Black or immigrant populations were systematically graded and outlined in red (“redlining”), flagging them as hazardous investment areas(21,33,64). This practice barred residents from these communities from receiving HOLC loans and thus systematically preventing the procurement of assets and accumulation of transferable wealth(33). While overt redlining is illegal today, prohibited under the Fair Housing Act of 1968, its effects have endured(65). Communities previously redlined have a persistent pattern of economic inequality and segregation(65).

Nardone and colleagues demonstrated that historical redlined census tracts have 2.4 times higher rates of asthma-related emergency department visits compared to census tracts deemed to be good investments(33). There are several indirect mechanisms in which redlining may lead to worse asthma and atopic dermatitis outcomes for Black and Latinx communities. Redlining led to an inequitable distribution of wealth and over generations has resulted in concentration of poverty, low rates of home ownership, and poor housing quality in Black and immigrant communities(33). In asthma and atopic dermatitis, there is a large body of literature documenting the negative effects of poor housing quality on outcomes(25,34–36). Presently, structural racism continues to operate by denying improved housing opportunities for communities of color via housing and mortgage discrimination(66). Due to these discriminatory practices, despite earning higher incomes, opportunities to move out of disinvested neighborhoods remain limited(66).

The lasting effects of redlining are also seen through the concentration of hazardous air pollutants in Black and immigrant communities(33,64), which have been demonstrated to be associated with asthma morbidity(67). Historically redlined census tracts were subjected to downstream policies, such as eminent domain, industrial zoning, and racial zoning,

which affected where highways and toxic hazard sites were built(33,64,68). Historically redlined census tracts have nearly twice as high diesel exhaust particulate (DEP) emissions as compared to non-redlined areas(33). This is particularly important when it comes to disparities in asthma and atopic dermatitis, which have been shown to be triggered by hazardous environmental exposures(25,69–72). Residential segregation, the contemporary manifestation of redlining, Jim Crow laws, and the legal separation of races, has also been linked to higher prevalence of asthma and worse disease outcomes for both asthma and atopic dermatitis(25,36,73,74). In a study examining asthma prevalence in low-birth weight children, Black children had higher rates of asthma as compared to non-Black children(74). However, when non-Black children lived in Black zip codes, defined as having greater than 50% of children living in the zip code who identified as Black, and exposed to the same environments, their rates of asthma were comparable(74). This suggests that structural environment impacts disease disparities, not biological differences between races(74). The systemic disinvestment in public and private sectors and concentrated industrialization within segregated communities of color has led to disproportionate exposure to environmental hazards(73), highlighting one mechanism of how segregation practice and policy lead to greater burden of asthma and atopic dermatitis in Black, Latinx, and Indigenous communities.

As a result of systemic disinvestment of communities of color, residential segregation is also associated with under resourced public services, including healthcare facilities(21,75,76) and healthcare providers(21,75), directly impacting the care that is accessible by Black, Latinx, and Indigenous communities. Residential segregation has led to highly segregated schools with poorer quality of education because of the lack of community resources and funding, caused by concentrated poverty and low property tax revenue(77). This has led to lower average test scores, fewer students in advanced placement courses, limited curriculum, less qualified teachers, less access to academic counseling and higher drop-out rates in segregated schools, all limiting future employment potential(77) and influencing socioeconomic position, a well-described risk factor for asthma prevalence and for morbidity in asthma and atopic dermatitis(9,78–82).

Socioeconomic Position

Similar to socioeconomic status, socioeconomic position (SEP) measures differential access to resources but also encapsulates social class and social stratification(78). Given the overlap in definitions, in this review SEP and SES are used interchangeably. SEP is strongly associated with the development of asthma, worse symptom burden, and higher health care utilization(78–81). There is a two-fold increase in the prevalence of asthma in individuals of low SEP as compared to those with high SEP(7). The link between SEP and the risk of atopic dermatitis is less clear(82). While studies have observed higher prevalence of atopic dermatitis in children and adults with higher SEP, severe atopic dermatitis is associated with lower SEP, lower income, dilapidated housing and living in a community with garbage in the streets(9,82).

While SEP is a strong predictor of atopic disease severity, it cannot be viewed independent of structural racism. In addition to lower educational opportunities, Black, Latinx and

Indigenous people have poverty rates (i.e., proportion living below the Federal Poverty Line) as high as 20.8%, 17.6% and 25.4%, respectively, as compared to 8.1% in White populations(83). As highlighted above, residential segregation has contributed to this difference, shaping the distribution of resources and reenforcing racial differences in education and employment opportunities(37,73). Structural racism and discrimination in both institutional and interpersonal levels have also contributed to racial disparities in SEP(37,39,73). Even at the same education level, Black and Latinx people receive less income as compared to their White counterparts and have markedly less wealth at equivalent incomes(37), barring generations of Black and Latinx people from escaping the cycle of poverty and the exposures associated with higher severity of atopic diseases.

Mass Incarceration

The US has the highest rate of incarceration in the world with a prison population of over 2 million(21,63). Structural racism at various levels of the criminal justice system has accounted for a gross over-representation of imprisoned Black, Latinx, and Indigenous people(63). Black Americans have the highest rates of incarceration at a level five times higher than White Americans(84). Latinx and Indigenous people are not far behind at two and four times, respectively, higher rates than their White counterparts(84,85). Despite studies showing that people of all races and ethnicities use and sell drugs at similar rates, Black men are imprisoned on drug charges at rates twenty to fifty times greater than their White counterparts(63).

Over-policing, the imposition of police control in minoritized communities at a level unlikely to occur in the dominant society, and imprisonment of racial and ethnic communities in the US can be traced back to the enslavement of Black and Indigenous people(21,63). Policing began with formation of slave patrols in the 18th century in effort to capture and retrieve runaway slaves(21). After the abolition of slavery, slave patrols evolved into contemporary police, which not only enforced the unequal laws that targeted communities of color, but also participated in the lynching of Black individuals(21). Policies set in this past half century have accelerated incarceration rates for Black, Latinx, and Indigenous populations. In 1971, President Nixon announced the war on drugs, directly leading to a sevenfold increase in the incarcerated population(63). This was followed by the Violent Crime and Law Enforcement Act during the Clinton administration, further enhancing the disparities in the mass incarceration(21,63). Recent evaluation of these policies demonstrates that the “war on drugs” and “tough on crime” policies, including stop-and-frisk laws, are deliberate and systematic examples of racism(86,87).

While literature exploring the relationship between incarceration and atopic diseases is in its infancy, a community-based study of approximately 2,000 adults found that a personal history of incarceration was associated with an increased prevalence of asthma, higher healthcare utilization and more severe asthma symptoms(88). We propose that the impact of mass incarceration on asthma and atopic dermatitis operates through three pathways: by enhancing racial socioeconomic inequities, by amplifying the effects of chronic psychological stress, and by exposing individuals to harmful physical environments (Figure 1). As a result of structural racism in the US legal system and policies

disproportionately enforced in minoritized communities, Black individuals in major cities are more likely to have criminal records, despite several reports documenting similar rates of committing crimes when compared to White populations(63,86,87). Upon release from prison, individuals with criminal records are subject to legal barriers, limiting employment and economic opportunities(63,89). This contributes to lower SEP and higher psychosocial stress, both associated with an increased risk of asthma(88–91). Incarceration also exposes individuals to stressful or traumatic environments, which may enhance the psychological stress response and thus predispose individuals to more severe asthma symptoms as discussed below(88,92). Similarly, parental incarceration can also be a source of chronic stress in childhood and has been well studied as one of the ten original factors included in the Adverse Childhood Experiences (ACEs) questionnaire(93,94). Higher exposure to ACEs and has also been associated with higher prevalence asthma in children and adults(95–98). Mass incarceration may also expose individuals to harmful physical environments including secondhand smoke, dilapidated prison conditions, indoor allergens such as pests and hazardous external air pollutants(88), all of which have been associated with asthma(69–71,99,100). Upon release, formerly incarcerated individuals are more likely to live in neighborhoods with substandard housing(88), thus further increasing the potential exposure to conditions known to be associated with asthma and atopic dermatitis(25,34–36).

BIOLOGIC EMBEDDING OF STRUCTURAL RACISM

Structural racism is biologically embedded over the life course(42). Figure 2 highlights empiric pathways by which racism may be embedded and contribute to immune dysregulation and the development or worsening of atopic disease. We recognize one pathway is through increased exposure to environmental hazards, specifically poor indoor and outdoor air quality. For this review, we focus on how structural racism may operate through the physiologic stress response to modulate immune function and promote atopic diseases through the following mechanisms: 1) T-helper (T_h)1/T_h2 polarization, 2) T_h17/regulatory T (T-reg) cell balance, 3) the microbiome, and 4) epigenetic modifications. Much of the evidence presented is drawn from the large empiric-base of biomechanisms of chronic psychosocial stressors at the individual level (i.e., socioeconomic status and perceived stress), as there is limited research directly examining the effects of structural racism on these biological processes. Future research in these areas would advance our understanding of the biomechanisms of structural racism.

Physiologic Stress Response

Stressful events stimulate activation of the hypothalamic-pituitary-adrenal (HPA) axis and the sympathetic nervous system (SNS), leading to the secretion of glucocorticoids (cortisol) and catecholamines (epinephrine and norepinephrine), respectively, into the bloodstream. These molecules exert effects by binding glucocorticoid receptors and beta(β)-adrenergic receptors present in lymphocytes and other immune cells(101,102). Chronic activation of these receptors leads to aberrant physiologic responses and desensitization, which increases allergic disease morbidity by reducing responsiveness to corticosteroid and β_2-agonist treatments(103). Among children with asthma, chronic life stress was associated with decreased expression of the glucocorticoid and β-adrenergic receptors(43).

Th1/Th2 Polarization—T helper (T_h) cells present allergens taken up by dendritic cells and have two predominant phenotypes, T_h1 and T_h2. T_h1 cells release Type 1 cytokines (IFN-γ and IL-2), whereas T_h2 cells produce Type 2 cytokines (IL-4, IL-5 and IL-13) that induce production of IgE and eosinophilia characteristic of atopic diseases(104). Dendritic cells also induce T_h2 cell proliferation when exposed to allergens such as cockroach antigen, a health hazard common in poor housing quality and urban environments(105,106) (107). We show in Figure 2 that differential exposure to environmental hazards may mediate the association between SEP and Th2 polarization, but studies have yet to explicitly investigate these potential pathways with downstream exposures resulting from structural racism. Extrapolating from literature exploring the relationship between SEP, psychosocial stress, and type 2 inflammation(108), one study found that Type 2 cytokines and circulating eosinophils were elevated in children of low SEP when compared to high SEP(92). This relationship between SEP and Th2 polarization was partially mediated by psychological stress in asthmatic children and adolescents(92,109). Subsequently, authors demonstrated that Th2 cytokine production by peripheral blood mononuclear cells (PBMC) stimulated with cockroach or dust mite antigen did not differ by SEP, suggesting that the SEP effect on Th2 polarization may operate through pathways independent of allergen exposures(110). Glucocorticoids and catecholamines may mediate stress-associated Th2 polarization, by inhibiting the production of Type 1 cytokines in T_h1 cells and promoting T_h2 phenotype(111,112).

Th17/Treg Balance—Recent work has also investigated the role of T_h17 cells in allergic pathogenesis(113). While effector T_h17 cells promote inflammation, regulatory T cells (T_{regs}) express forkhead box P3 (FoxP3) and limit excessive inflammatory responses. Psychosocial stressors may promote inflammation by decreasing the number of T_{regs} and enhancing T_h17 cell differentiation. T_h cells from low-SEP asthmatic children had elevated expression of RORγt, a transcription factor critical for T_h17 cell function(114). The effect of psychosocial stressors on T_h17/ T_{reg} balance may be mediated by cortisol(115). PBMCs treated with a synthetic glucocorticoid at concentrations equivalent to cortisol levels observed during high stress periods had decreased FoxP3 expression(116). T_h17 differentiation is also regulated by IL-6, a proinflammatory cytokine elevated in individuals from racially segregated communities(117), by activating the signal transducer and activator of transcription 3 (STAT3) protein and releasing Foxp3 from RORγt(118).

Microbiome—Psychosocial stressors may produce shifts in gut microbial diversity that contribute to allergic pathogenesis. For example, infants born to mothers with high prenatal stress and/or elevated cortisol levels had a greater abundance of pathogenic Proteobacteria in their gut microbiome and higher reports of allergic reactions(119). Respiratory microbial communities may also contribute to the development of atopy. Children living in urban environments with uncontrolled asthma had nasopharyngeal microbiomes dominated by Moraxella, a type of Protobacteria, that was also associated with increased eosinophilic inflammation(120). In children with severe asthma, bronchial Proteobacteria positively correlated with T_H17-related gene expression in airway epithelia(121).

Epigenetic modifications—Biochemical alterations to the DNA, such as methylation and histone modifications, influence gene expression and accessibility. Allergic asthma was previously associated with differentially methylated genes in the nasal epithelia(122). Psychosocial stressors may also induce epigenetic changes that increase susceptibility to allergic disease(123). Methylation of ADCYAP1R1 was associated with both exposure to violence and increased asthma odds in a study of Puerto Rican children(124). Chronic stress may also impact epigenetic regulation of genes involved in T_h cell polarization(125).

CONCLUSION

By fostering discriminatory policies and practices, government and institutions have reinforced the inequitable distribution of resources and opportunities for Black, Latinx and Indigenous people via residential segregation, socioeconomic position, and mass incarceration. These upstream pathways of structural racism have led to inequity in the physical and social environment that are associated with alterations in biological processes, including the physiological stress response, that may contribute to the increased risk for atopic disease and severe symptoms. Exposure to inhaled environmental pollutants may also increase risk of allergic respiratory disease by altering the airway microenvironment and activating neuroendocrine mediators(126,127).

To address racial and ethnic disparities, the field of allergy and clinical immunology must take part in dismantling the proximal effects of structural racism. This is not a simple feat, as these factors are rooted in centuries of discrimination and enslavement. Additional investigation is needed to understand the health impact of racism, including further elucidating the biological processes and physiological responses associated with experiencing the effects of structural racism. Research is also needed to identify ways in which the effects of racism can be mitigated through community based participatory research. This should be done simultaneously with efforts to address the root causes of health disparities. Avenues to achieving a more diverse research workforce reflecting Black, Latinx and Indigenous communities is also needed. To truly address health disparities caused by structural racism, the medical and research community must actively participate in policy reform, advocacy, community re-development and place-based partnerships.

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Abbreviations

US	United States
FLG-LOF	Filaggrin Loss of Function
HOLC	Home Owners’ Loan Corporation
DEP	Diesel Exhaust Particulate

SEP	Socioeconomic Position
ACE	Adverse Childhood Experiences
Th	T-Helper
T-reg	Regulatory T
HPA	Hypothalamic-Pituitary-Adrenal
SNS	Sympathetic Nervous System
B	Beta
PBMC	Peripheral Blood Mononuclear Cells
FoxP3	Forkhead Box P3
STAT3	Signal Transducer And Activator Of Transcription 3

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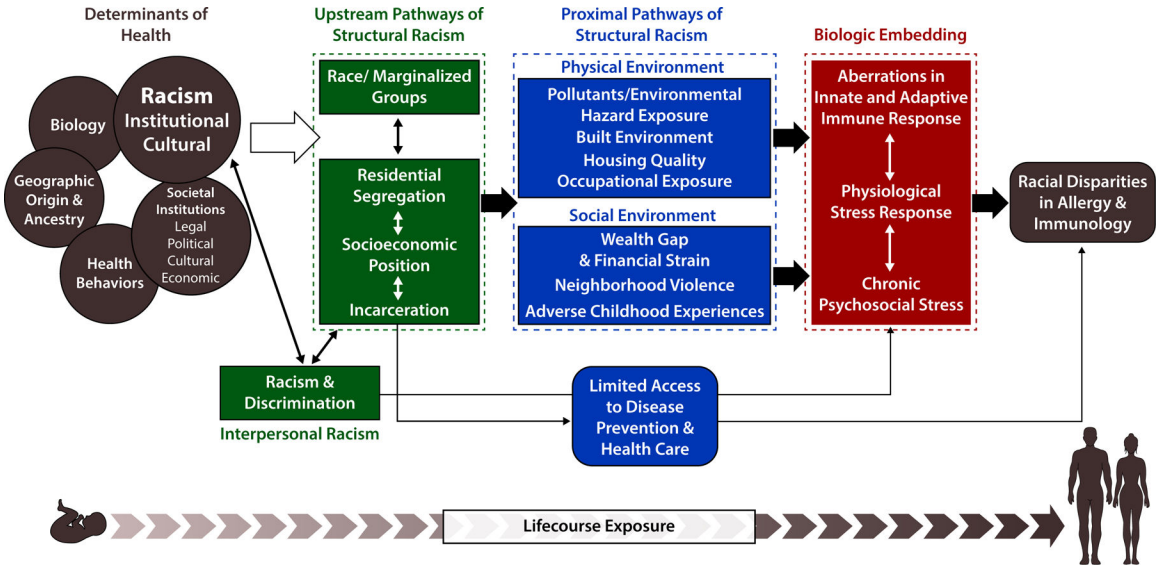

Figure 1. Structural Racism as a Root Cause of Allergy and Immunology Disparities.

Conceptual framework of the upstream and proximal pathways of structural racism and its effect on health. Framework adapted from the work of Williams and Mohammed(29,30), Bailey(19,21), and the World Health Organization's Commission on Social Determinants of Health framework(31)

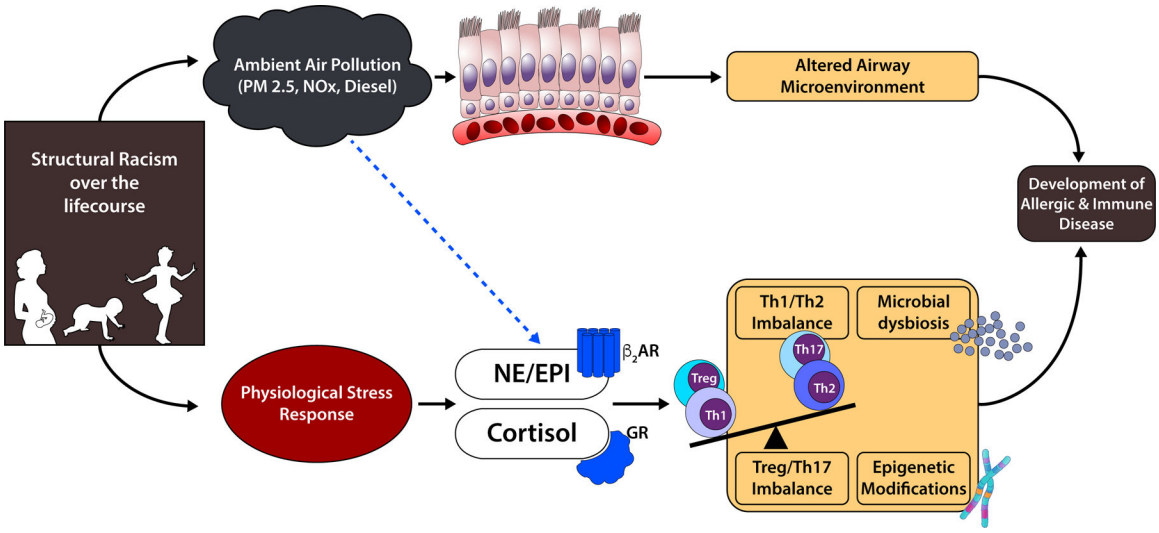

Figure 2. Empiric Pathways for Biologic Embedding of Structural Racism.

Structural racism may modulate immune function and promote atopic diseases through the following mechanisms: 1) T-helper (Th)1/Th2 polarization, 2) Th17/regulatory T (T-reg) cell balance, 3) the microbiome, and 4) epigenetic modifications