



# The Relationship of Historical Redlining with Present-Day Neighborhood Environmental and Health Outcomes: A Scoping Review and Conceptual Model

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Accepted: 31 May 2022  
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**Abstract** Following the Great Depression and related home foreclosures, the federal government established new agencies to facilitate access to affordable home mortgages, including the Home Owners' Loan Corporation (HOLC) and Federal Housing Administration (FHA). HOLC and FHA directed widespread neighborhood appraisals to determine investment risk, referred to as “redlining,” which took into account residents’ race. Redlining thereby contributed to segregation, disinvestment, and racial inequities in opportunities for homeownership and wealth accumulation. Recent research examines associations between historical redlining and subsequent environmental determinants of health and health-related outcomes. In this scoping review, we

assess the extent of the current body of evidence, the range of outcomes studied, and key study characteristics, examining the direction and strength of the relationship between redlining, neighborhood environments, and health as well as different methodological approaches. Overall, studies nearly universally report evidence of an association between redlining and health-relevant outcomes, although heterogeneity in study design precludes direct comparison of results. We critically consider evidence regarding HOLC’s causality and offer a conceptual framework for the relationship between redlining and present-day health. Finally, we point to key directions for future research to improve and broaden understanding of redlining’s enduring impact and translate findings into public health and planning practice.

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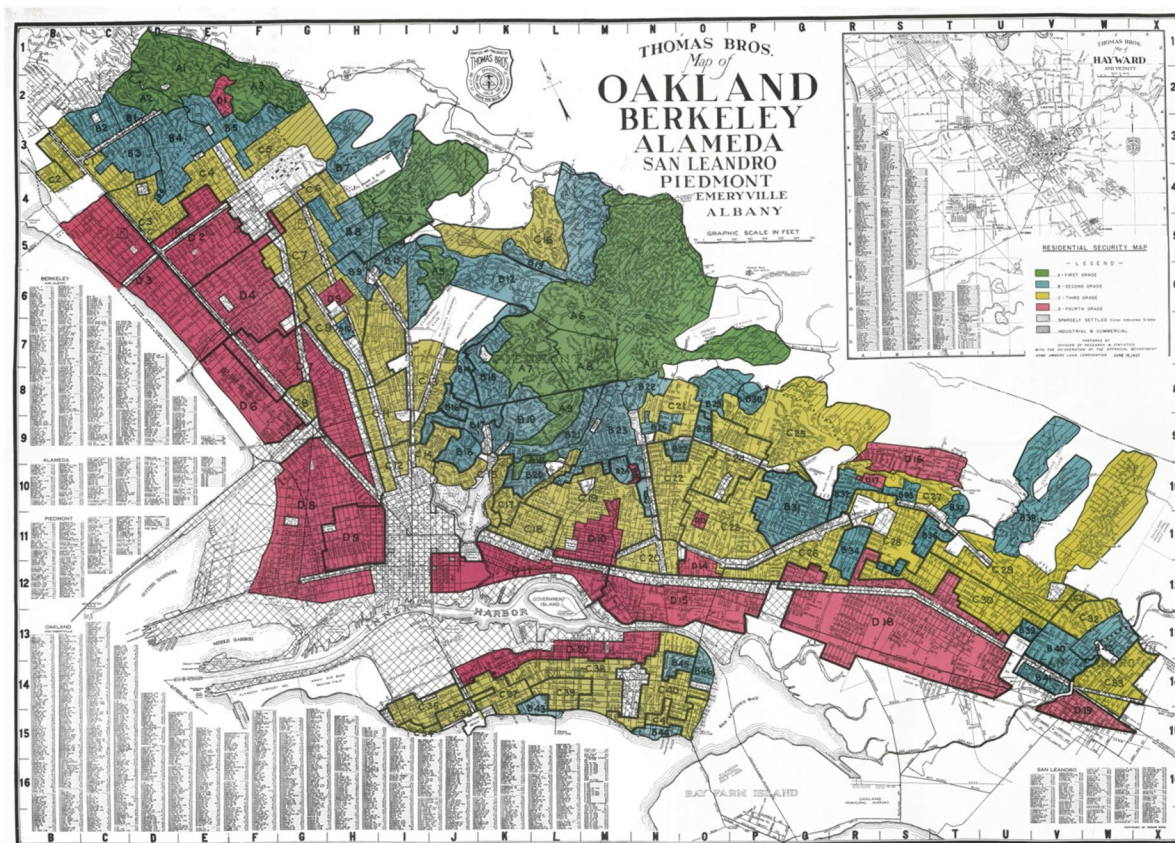
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**Keywords** Housing · HOLC · Health disparities ·  
Structural racism · Segregation · Environmental  
justice

## Introduction

To stabilize housing markets and homeownership following the Great Depression, the federal government established the Home Owners’ Loan Corporation (HOLC) — which offered refinancing assistance to struggling homeowners, purchasing their mortgages and reissuing amortized mortgages with longer repayment timelines — as well as the Federal Housing



**Fig. 1** HOLC map of Oakland, CA. Published by the Mapping Inequality project [7] under a Creative Commons Attribution-Non-Commercial-ShareAlike 4.0 International License (<https://creativecommons.org/licenses/by-nc-sa/4.0/>).

Administration (FHA) — which underwrote mortgage risk to increase banks' comfort with mortgage lending. In consultation with local financial and real estate informants, these agencies conducted widespread neighborhood appraisals of investment risk in the form of color-coded “residential security” maps (Fig. 1) — typically ranking neighborhoods from “A,” best, to “D,” hazardous. The practice of ranking neighborhoods as hazardous and credit-unworthy is referred to as “redlining,” after the color assigned to “D” grade neighborhoods on these maps [1–5].

Among other factors, the assessments explicitly considered neighborhood residents' race and ethnicity, with the presence of people of color, immigrant, and/or Jewish residents typically considered detrimental. In particular, almost no neighborhoods noted to include Black and East Asian or Filipino residents received “A” or “B” ratings [6, 7]. Redlining deepened

neighborhood racial residential segregation [2, 8], and Black and other prospective homebuyers of color were disproportionately shut out from favorable loan terms and new housing developments — contributing to long-term disinvestment in their neighborhoods [1, 9]. Recent research points to the persistence of present-day economic disadvantage in formerly redlined neighborhoods, including higher poverty, vacancy rates, risk of loan denials, subprime lending, and mortgage default, and lower economic mobility, homeownership rates, and home values [8, 10–12]. However, another plausible effect of redlining — on health — has until recently been underexplored.

Following the recent digitization of HOLC maps [7, 13], a growing number of studies assess redlining's association with present-day environmental determinants of health and health outcomes. Lee et al. examined 12 studies of redlining and

health in a recent systematic review [14], finding that overall redlining was associated with a range of adverse health outcomes. However, no review has yet included studies on the relationship between redlining and environmental determinants of health.

In this scoping review, we summarize the literature on the relationship between historical redlining and subsequent environmental determinants of health and health outcomes, including 21 studies not included in Lee et al.'s review. We assess the range of outcomes studied, conceptual framing, variation in study geography and design, and extent of the current evidence regarding the direction and strength of the relationship between redlining and health-relevant outcomes with the purpose of informing future work in this area. We build on Lee et al.'s review through an expanded discussion of study design characteristics and conceptual approaches, and conclude by offering a conceptual framework for understanding the role of redlining in contributing to health disparities and identifying directions for future research.

## Methods

Scoping reviews provide an overview of evidence on a topic, assessing the current extent of coverage as well as the range and characteristics of studies. They are best suited for assessing the scope of the current body of evidence, understanding how research is being conducted on the topic, identifying knowledge gaps, and clarifying key concepts [15]. They can therefore be valuable when a topic has not yet been comprehensively reviewed [16], as in our case. We followed a structured process proposed by Arksey and O'Malley [17] and elaborated by Levac et al. [18], and further developed into the PRISMA extension for scoping reviews checklist [19].

### Search Strategy

Articles were included if they were published in English, in a peer-reviewed journal, and quantitatively and/or geographically examined the relationship between historical HOLC or FHA redlining and a subsequent health outcome or environmental determinant of health. The search query used was the formulation relevant to the search engine of the combination of "redlining OR HOLC" AND "health OR

environment". We searched PubMed and Web of Science for relevant studies on September 15, 2021. We did not set limits on publication date. After excluding duplicates, articles were identified for inclusion based on an initial screen of abstracts followed by a full text review. Subsequently, a manual backward citation search and forward citation search in Google Scholar were used to identify five additional articles that met the inclusion criteria. We updated the results in March 2022 to add 8 additional studies published since our initial search. The search process is shown in Fig. 2 (a bibliography of all papers considered is provided in Appendix 1).

### Data Extraction and Synthesis

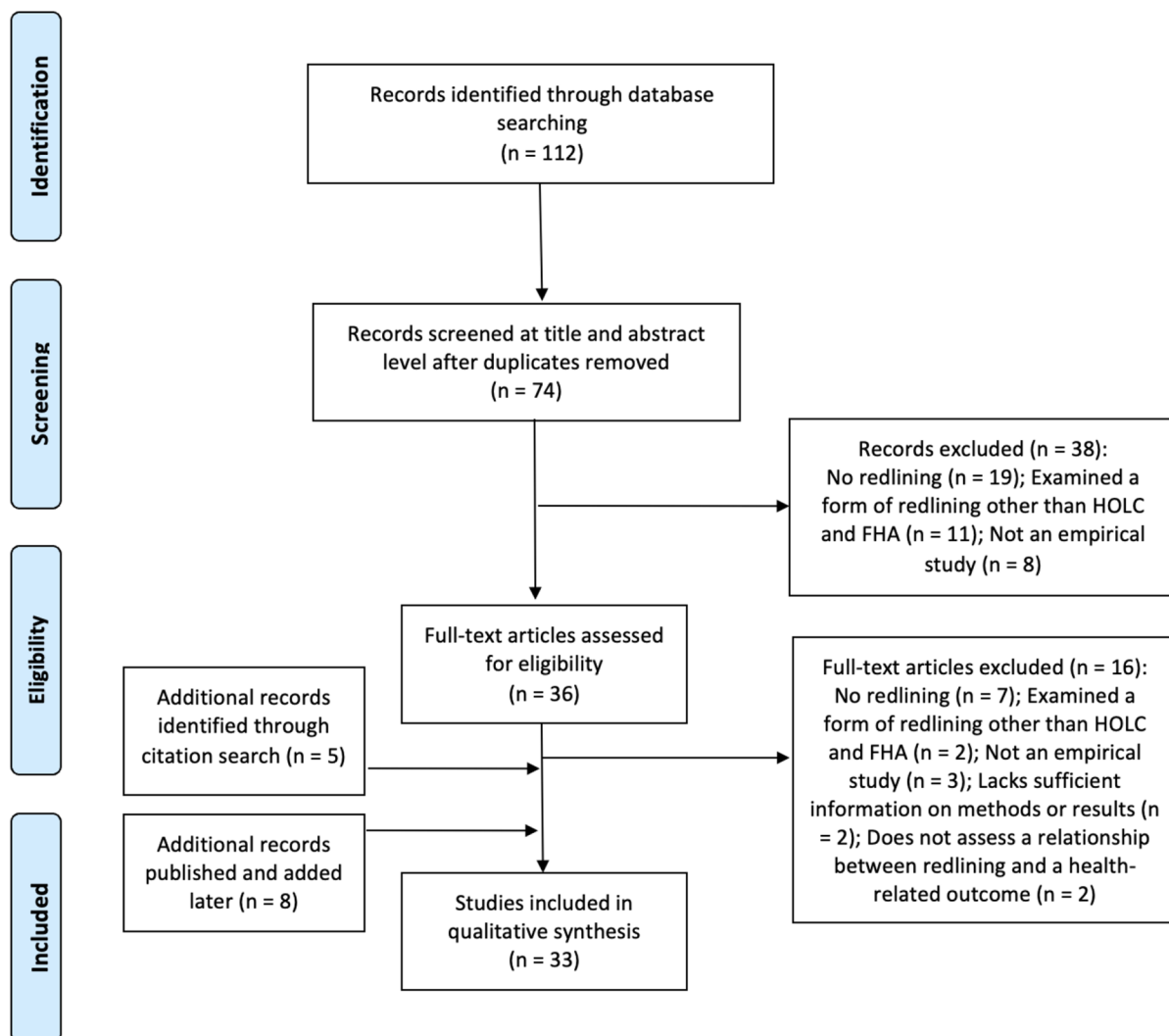
Key study characteristics were extracted and entered into a standardized chart. A draft extraction form was developed collaboratively by the authors prior to the search. Following study selection, authors conducted a trial of the extraction form with two studies to ensure relevance and completeness, and continued to make updates to the chart on an iterative basis. Data extraction was conducted by CS, with secondary review by LJC for more complex studies. Researchers met regularly to discuss findings, with particular attention to connecting included studies' design and insights to literature on redlining from other fields such as economics and history.

## Results

Thirty-three articles were selected for inclusion. The vast majority (30) were published in 2020 or later, and the earliest publication date was 2017. All studies used HOLC grades as the indicator for redlining. All studies were quantitative and assessed outcomes at one time point only (except for two studies that incorporate longitudinal analysis of a short trajectory in the present day [20, 21]). Based on author affiliations and journal of publication, most studies came from a public health discipline, while fewer arose from urban planning, geography, or environmental and sustainability studies.

### Conceptual Framework

Studies typically conceptualized HOLC grades as exerting an active, potentially causal effect on the



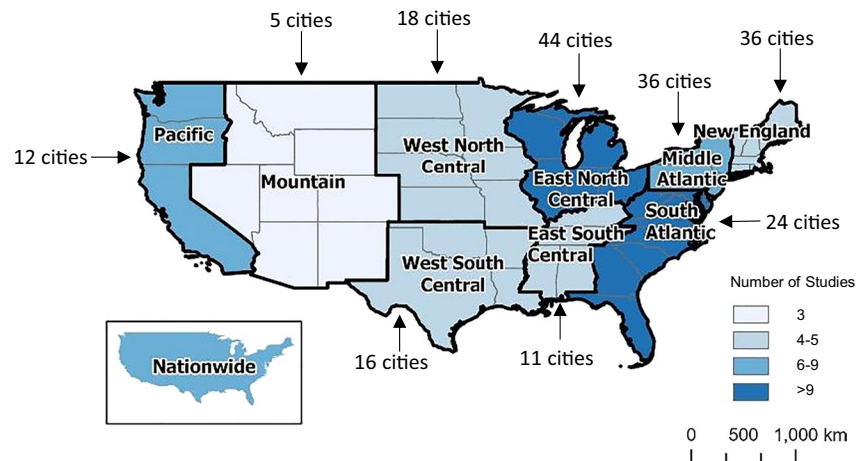
**Fig. 2** PRISMA flowchart showing the study selection process

outcome of interest through some combination of pathways relating to racial segregation, capital disinvestment, and reduced wealth accumulation from homeownership. There were several exceptions in which studies posited potential limitations to HOLC's direct effect. For example, Jacoby et al. viewed HOLC grades as a "spatial representation of place-based racial discrimination" that was not necessarily directly influential in lending patterns itself [22]. Similarly, Huang and Sehgal point to HOLC maps as "a proxy for de jure and de facto government policy" rather

than conceptualizing them as having "by themselves caused" health impacts [23]. And Benne et al. recognized debate over how HOLC maps were actually used, but argued regardless, they "represent a striking visual representation of the institutional racism that was prevalent" at the time [24]. Studies frequently situated redlining as a process of structural or institutional racism. One study drew on theories of social production of space [25], three on ecosocial theory [26–28], and another on political ecology [21]. Only three studies included a conceptual diagram [29–31].



**Fig. 3** Geographic distribution of studies reporting results specific to a particular city or state ( $N=33$ ), and indicating with arrow the number of cities per region with redlining maps digitized by mapping inequality to date



### Location

Studies focused on a single city (13 studies); multiple cities within a region or state (8); all possible HOLC graded areas (7); or multiple cities nationwide (5). Geographical distribution is shown in Fig. 3.

### Outcomes

Seventeen studies examined health-related outcomes (Table 1), while 13 examined environmental determinants of health (Table 2); three examined both types (Table 3). Categories of health-related outcomes included chronic conditions (5 studies), maternal and infant health (5), general health (4), injury (3), mental health (2), infectious disease (2), health behavior (2), preventive measures (2), heat-related illness (1), childhood lead poisoning (1), and surgery (1). Studies of environmental determinants focused on the biophysical (10) and retail (6) environments. Most studies examined only one outcome, or several closely related outcomes; only a few studies examined multiple unrelated outcomes [23, 29, 32, 33]. Studies varied in the spatial precision of the outcome data available, including individual point locations (e.g., retail or residential address) (10), census tract (CT) (11), gridded raster area (7), zip code or zip code tabulation area (4), locally defined neighborhood (2), census block (1), and city block (1); in one case, it was not stated. The time period of the outcome(s) in almost all studies was 2000 or later, except one study utilizing data from 1951 [34].

### Unit of Analysis and Assignment of HOLC Grade

Studies utilized a variety of units of analysis, including individuals (e.g., patients) (8) and geographic units: HOLC polygons, i.e., boundaries of HOLC-graded area (6); present-day (4) or 1940 (1) CTs; census block groups (3); census blocks (2); zip code tabulation areas (2); locally defined neighborhood areas (2); residential tax parcels (1) and properties (1); census incorporated or designated places (1); and new units created through the intersection of HOLC polygons and census-defined units (3). Ten studies included ungraded areas in their analysis. Studies in which there was spatial misalignment between the unit of analysis and the historic HOLC boundaries assigned HOLC grade to the unit of analysis in different ways. One approach was to create new geographic units based on the intersection of HOLC boundaries and census geographies [24, 32, 35]. Other studies assigned HOLC grade on the basis of the internal centroid of the unit of analysis [22, 33, 36] or assigned the grade covering the largest amount of area for each unit, with or without a threshold [23, 25, 28, 30, 31, 37, 38]. One study assigned the highest grade contained in the unit of analysis [39]. One study created a category for both grades if the unit of analysis included area from two grades (e.g., C and D combined), as well as a category for units of analysis containing area from any three grades [40]. Five studies, rather than assigning a single grade, calculated the proportion of the unit of analysis graded D or each grade [20, 29, 41–43]. In at least two cases, the method of HOLC grade assignment was not clear.

**Table 1** Studies assessing the association between historical HOLC grade and subsequent health-related outcomes

Location	Outcome(s)	Unit of analysis (sample size)	HOLC variable	Control variables <sup>a</sup>	Abbreviated findings [95% CI]
Benns et al. [24]	Louisville, KY Number of gunshot victims	Modified census block groups (N=310)	Categorical: A, B, C, D (ref), ungraded	Population density, sociodemographic characteristics	Compared to D-graded areas, A-graded areas were associated with lower incidence of gunshot victims (IRR=0.22 [0.07, 0.61])
Diaz et al. [38]	Nationwide 30-day (1) mortality, (2) postoperative complications, and (3) readmissions	Patients hospitalized for certain surgeries (N=212,179)	Categorical: A (ref), B, C, D	Age, sex, comorbidities, urgency of admission, type of operation, hospital characteristics, CT	Patients residing in D-graded areas had higher odds of mortality (OR=1.23 [1.13–1.34]), complications (OR=1.12 [1.07–1.17]) and readmissions (OR=1.06 [1.01–1.11]) compared to those residing in A-graded areas. Associations were attenuated after additional control for neighborhood deprivation
Hollenbach et al. [40]	9 counties in the Finger Lakes region of NY Primary: Preterm and periviable birth Secondary: Prevalence of 6 obstetric and medical complications <sup>c</sup>	Live births (N=64,804)	Categorical: A (ref), B and C, C, C and D, D, 3 or more designations	Model 1: zip code poverty levels and educational attainment; Model 2: maternal and paternal race	D-graded areas were associated with higher prevalence of preterm birth compared to A-graded areas, when adjusting for community characteristics (OR=1.46 [1.08–1.97]), as well as when adjusting separately for parental race (OR=1.38 [1.25–1.53]). D-graded areas also linked to higher unadjusted prevalence of all secondary outcomes; greatest effect size for severe maternal depression (OR=4.40 [3.15–6.17])
Huggins [34]	Austin, TX Number of cases or deaths from tuberculosis, 1951	HOLC polygons (N not stated)	Categorical: D vs. all other areas	None	Some but not all redlined areas had a higher number of tuberculosis cases per unit area
Jacoby et al. [22]	Philadelphia, PA Number of (1) firearm assaults and (2) violent crimes	1940 census tracts (CT) (N=404)	Categorical: A (ref), B, C, D, ungraded	1940 sociodemographic characteristics, present-day population size	Relative to exclusively A-graded areas, D grade was associated with higher incidence of firearm assaults (IRR=8.73 [2.24, 36.34]). Ungraded areas were associated with higher incidence of violent crimes (IRR=4.53 [1.57, 17.29]), but the relationship was not statistically significant for D grade (IRR=2.57 [0.91, 11.00])

Table 1 (continued)

Location	Outcome(s)	Unit of analysis (sample size)	HOLC variable	Control variables <sup>a</sup>	Abbreviated findings [95% CI]
Krieger et al. [37]	Late stage at diagnosis for cervical, breast, lung, and colorectal cancer	Individuals with cancer (N=53,186)	Categorical: A/B combined (ref), C, D, ungraded, mixed <sup>1</sup>	Age at diagnosis, sex/gender, race/ethnicity	Residence in a D-graded CT, compared to A- or B-graded CT, was associated with increased risk of late-stage diagnosis of lung cancer among men (RR = 1.07 [1.02, 1.13]) and breast cancer for women (RR = 1.07 [0.98, 1.17])
Krieger et al. [30]	Preterm birth	Singleton births (N=528,096)	Categorical: A (ref), B, C, D, other (ungraded or less than 50% of land in one HOLC category)	Maternal age, nativity, education, race/ethnicity; additional separate models also control for present-day CT poverty and racialized economic segregation	Residence in a D-graded CT was associated with elevated risk compared to an A-graded CT (OR = 1.18 [1.05, 1.32]) when controlling for maternal characteristics alone. When additionally controlling for current poverty, risk was similar (OR = 1.14 [1.02, 1.28]). The association was attenuated with control for present-day racialized economic segregation in addition to maternal characteristics (OR = 1.07 [0.96, 1.20]) <sup>d</sup>
Li and Yuan [39]	(1) Cumulative percentage of people who tested positive for Covid-19, and (2) cumulative death rate from Covid-19	Zip code tabulation area (ZCTA) (N=165)	Categorical: A (ref), B, C, D	Racial/ethnic composition, SES, population 65+, average household size, Covid-19 test rate, number of days tracked	Grades of B and C, although not D, were associated with a higher rate of Covid-19 infection as compared to A, but not a higher death rate. The association decreased over time
Lynch et al. [29]	(1) Average infant mortality rate Prevalence of adults who reported having poor (2) mental or (3) physical health, for ≥ 14 days	CT (N=123)	Continuous measure of redlining ranging from 0.5 to 4 <sup>e</sup>	None	1 unit increase in redlining score was associated with increase in the percent of adults reporting poor mental ( $\beta = 1.26$ [0.51, 2.01]) and physical health ( $\beta = 1.34$ [0.40, 2.28]). However, it was not associated with infant mortality rate ( $\beta = -0.48$ [-2.12, 1.15])

Table 1 (continued)

Location	Outcome(s)	Unit of analysis (sample size)	HOLC variable	Control variables <sup>a</sup>	Abbreviated findings [95% CI]
McClure et al. [20] <sup>f</sup>	Self-rated health, ranging from 1 to 5	Locally defined neighborhood (N = 54) Individual (N = 1471)	Continuous measure of % of locally defined neighborhood graded D	None	A 10%-point increase in redlined area in a neighborhood was associated with 0.56 [-0.10, 1.28] increase in neighborhood prevalence of poor self-rated health, and 0.23 [-0.06, 0.57] increase in within-person probability of experiencing poor self-rated health
Mujahid et al. [27]	Ideal cardiovascular health (CVH) summary measure, <sup>g</sup> ranging from 0 to 14	Individual (N = 4779)	Categorical: A (ref), B, C, D	Age, sex, level of education, family income	Living in poorer-graded neighborhoods was associated with CVH, compared to those residing in A-graded areas, only among Black participants (B-graded PR = -1.09 [-1.80, -0.38], C-graded PR = -0.83 [-1.53, -0.12], D-graded PR = -0.82 [-1.54, -0.10]). No associations for white, Hispanic, or Chinese participants (D-grade white PR = -0.33 [-0.80, 0.15])
Nardone et al. [36]	Total age-adjusted rates of ED visits for asthma	CT (N = 1431)	Categorical: A (ref), B, C, D	Diesel exhaust, average annual ambient PM2.5 concentration, poverty rate, city random effect	Compared to A, D grade was associated with higher rate of ED visits due to asthma (RR = 1.39 [1.21, 1.57]), leading to 15.6 [8.8, 23.3] additional ED visits per 10,000 residents per year
Nardone et al. [33]	Prevalence of 14 health indicators among adults <sup>h</sup>	CT (N = 4061)	Categorical: comparison not stated	None	Cancer, poor mental health, and lack of health insurance showed the strongest correlation with redlining, while there was little correlation between redlining and high blood pressure, congestive heart disease, and Pap smears



**Table 1** (continued)

Location	Outcome(s)	Unit of analysis (sample size)	HOLC variable	Control variables <sup>a</sup>	Abbreviated findings [95% CI]
Nardone et al. [26]	Los Angeles, Oakland, and San Francisco, CA 1) Preterm birth (PTB), 2) low birth weight (LBW), 3) small-for-gestational age (SGA), and 4) perinatal mortality (PM)	Individual (N=651,620)	Categorical: adjacent grades (B vs. A, C vs. B, and D vs. C)	1940 CT socioeconomic characteristics	Without propensity score matching, prevalence of PTB, SGA, and PM was significantly higher in C- and D-graded areas, compared to A-graded areas. Adjusted models using a restricted propensity score matched sample indicated higher odds of PTB (OR = 1.02 [1.00–1.05]) and SGA (OR: 1.03 [1.00–1.05]) associated with C grade, relative to B. D grade was associated with reduced odds of PTB (OR = 0.93 [0.91–0.95]), LBW (OR = 0.94 [0.92–0.97]), and SGA (OR = 0.94 [0.92–0.96]) relative to C <sup>i</sup>
Poulson et al. [44]	Boston, MA Rate of shootings (assaults and homicides involving a firearm) per 1000 people	Census block (N=7530)	Categorical: A/ ungraded combined (ref), B, C, D	None	D grade was associated with higher incidence rate of shootings compared to A/ungraded areas (IRR = 11.1 [5.5, 22.4])
White et al. [32]	14 urban areas nationwide Prevalence of 7 health indicators among adults <sup>k</sup>	Modified census blocks (N = not stated)	Categorical: A, B, C, D (ref)	None <sup>l</sup>	Relative to A, D grade was associated with a higher odds of chronic heart disease, smoking, diabetes, no physical activity, no health insurance, and obesity in 5–13 out of 13 total cities. Odds of a routine health check up in the last year were lower in 7 cities
Wright et al. [28]	28 urban areas in MA Incidence of primary invasive breast cancer, overall and by tumor estrogen (ER +, ER -) and progesterone (PR +, PR -) receptor status	Census tract (N=474)	Categorical: A/B combined (ref), C, D, ungraded, mixed <sup>l</sup>	Individual-level race	C and D grades were associated with a reduced risk of breast cancer relative to A/B (D-grade IRR = 0.94 [0.88, 1.01] and C-grade IRR = 0.97 [0.92, 1.03]). Mixed grade and no grade were associated with higher risks (IRR = 1.05 [0.98, 1.12] and 1.01 [0.95, 1.07], respectively)

**Table 1** (continued)

CT census tract; *IRR* incidence rate ratio; *OR* odds ratio; *PR* prevalence ratio; *RR* risk ratio

<sup>a</sup>Unless otherwise specified, all studies examined outcomes close to the present day (2000 and later).

<sup>b</sup>Zip codes containing both areas graded B and areas graded C.

<sup>c</sup>Pregnancy-associated hypertension, severe maternal depression, NICU admission, 5 min APGAR score <7, substance use, exclusive breastfeeding.

<sup>d</sup>Index at the concentration at the extremes comparing high-income White households vs. low-income Black households.

<sup>e</sup>Tracts with 100% of their area graded D had a score of 4.

<sup>f</sup>The primary exposure of interest was foreclosure rate recovery. Redlining was considered as a confounder and effect modifier of the association between foreclosure rates during the 2007–2008 Great Recession and self-rated health.

<sup>g</sup>Consists of 7 risk factors (blood pressure, fasting glucose, cholesterol, body mass index, diet, physical activity, and smoking)

<sup>h</sup>With current asthma, (2) diagnosed with a nonmaternal cancer, (3) ever diagnosed with angina or coronary heart disease, (4) ever diagnosed with diabetes, (5) told they have high blood pressure in past year, (6) reporting 14 days of poor mental health in the past month, (7) ever diagnosed with a stroke, (8) reporting binge drinking in last 30 days, (9) currently smoking every day or some days, (10) with current obesity, (11) reporting an average of <7 h of sleep, (12) reporting having no current health insurance coverage, (13) receiving a Pap smear in past 3 years, (14) with high blood pressure who are taking hypertension medication.

<sup>i</sup>Estimates were similar in sensitivity analyses adjusting for maternal covariates of maternal age, parity, and year of birth. Secondary analyses of very PTB, very LBW, and neonatal mortality found elevated odds associated with C versus B grade and reduced odds of very PTB associated with D versus C.

<sup>j</sup>Secondary analysis controls for CT poverty.

<sup>k</sup>Ever diagnosed with chronic heart disease, (2) went to doctor in last year for routine checkup, (3) currently smoking every day or most days, (4) ever diagnosed with diabetes, (5) reporting no leisure-time physical activity in last month, (6) with current obesity (BMI  $\geq 30$  kg/m<sup>2</sup> with certain exceptions), (7) without health insurance

<sup>l</sup>Mixed areas had  $\geq 50\%$  of land area in HOLC-graded areas, but no HOLC grade accounting for  $\geq 50\%$  of land area. In contrast, ungraded areas had <50% of their land in HOLC-graded areas

**Table 2** Studies assessing the association between historical HOLC grade and subsequent environmental determinants of health

	Location	Outcome(s)	Unit of analysis (sample size)	HOLC variable	Control variables	Abbreviated findings
Hoffman et al. [48]	108 urban areas nationwide	(1) Summertime land surface temperature (LST) (2) Developed impervious surface land cover (3) Tree canopy cover-age	HOLC polygons (N not stated)	Categorical: A, B, C, D	None	LST was elevated in D- relative to A-graded areas in 94% of urban areas (2.6 °C warmer on average). Impervious surface land cover was higher in D-graded areas and tree canopy cover was lower
Lane et al. [43]	202 urban areas nationwide	Annual ambient concentration predictions of (1) nitrogen dioxide (NO <sub>2</sub> ) and (2) fine particulate matter (PM <sub>2.5</sub> )	Census block (N=562,078)	Categorical: A, B, C, D	None	Across all cities, NO <sub>2</sub> concentrations are 56% higher in D-graded areas than A-graded areas, while PM <sub>2.5</sub> concentrations are 4% higher. Population-weighted mean NO <sub>2</sub> levels were higher in D-graded areas than overall in 80% of cities (55% for PM <sub>2.5</sub> ), and were lower in A-graded areas than overall in 84% of cities (68% for PM <sub>2.5</sub> )
Lee et al. [25]	6 cities, San Francisco Bay Area, CA	Density of off-premise alcohol outlets	Census block groups (N=520)	Categorical: A (ref), B, C, D, ungraded	Local and adjacent population, median household income	D grade was associated with higher density of off-premise alcohol outlet density relative to A grade (RR = 1.90 [0.81, 4.84])
Li & Yuan [31]	102 urban areas nationwide	mRFEI Index of healthiness of the food environment, ranging from 0 (worst) to 100 (best)	Census tract (N=11,651)	Categorical: A (ref), B, C, D, ungraded (<50% of land graded)	CT sociodemographic characteristics and city-level racial segregation and natural log of the population	D-graded areas had 0.83 [0.77, 0.97] times the mRFEI score of A-graded areas

Table 2 (continued)

Location	Outcome(s)	Unit of analysis (sample size)	HOLC variable	Control variables	Abbreviated findings
Locke et al. [63]	Tree canopy coverage	HOLC polygon (N = 3188)	Categorical: A (ref), B, C, D	City random effect	D grade was associated with decreased percent tree canopy cover relative to A grade (M = -20.79 percentage points [-22.27, -19.31])
Nardone et al. [45]	Summer and annual average NDVI, ranging from -1 (least green) to 1 (most green)	HOLC polygon (N = 4141)	Categorical: adjacent grades (B vs. A, C vs. B, and D vs. C)	1940 CT socioeconomic characteristics, 1940 population density, ecoregion, Census region	Unadjusted annual average mean NDVI increased on a gradient from D to A grade. Poorer HOLC grade was associated with a 0.024–0.39 unit decrease in annual average NDVI compared to the adjacent grade in adjusted models using a restricted, propensity score matched sample
Nowak et al. [77]	Tree cover, impervious cover, tree cover stocking (proportion of non-impervious area occupied by tree canopies), and ecosystem service value (pollution removal, carbon sequestration, avoided runoff)	Census incorporated and designated places (N = 1259)	Categorical: A, B, C, D	None	Poorer grade was associated with lower % tree cover, % stocking, and ecosystem service values, and higher % impervious cover. For example, tree cover was about twice as high a proportion of A-graded areas as D-graded areas. 88.6% of cities had greater % tree cover, and 86.4% had lower % impervious cover, in A-graded areas than D-graded areas

**Table 2** (continued)

Location	Outcome(s)	Unit of analysis (sample size)	HOLC variable	Control variables	Abbreviated findings
Sadler et al. [47]	Healthy food access score ranging from 1 to 1145	Residential tax parcels (N not stated)	Continuous variable with change from A to B, B to C, and C to D considered 1 unit increase	Socioeconomic distress index, racial composition, housing age	A 1-unit increase in redlining was associated with a 48–52 point increase in food access score
Saverino et al. [41]	Afternoon mean temperature during a heat wave	Census block group (N not stated)	Continuous: quartiles of proportion A/B combined and C/D combined	None	Areas in the fourth quartile of percentage C- or D-graded were on average 0.53 °C warmer than areas in the lowest quartile, while areas in the fourth quartile of percentage A- or B-graded were on average 0.26 °C cooler than areas in the lowest quartile
Schinasi et al. [46]	Land cover and housing characteristics linked to enhanced heat vulnerability, including roof color, shape, and color combined, and presence of immediately adjacent mature or immature tree canopy	Residential properties (N=400)	Categorical: A (ref), B, C, D	1940 racialized economic segregation and CT sociodemographic characteristics	Compared to properties in A-graded areas, properties in D-graded areas had elevated risk of low or no mature tree canopy, in both models adjusting for historic characteristics (RR = 5.09 [2.78–9.32]) and for present-day characteristics (RR = 5.96 [5.76, 6.16])
Schwartz et al. [35]	Tobacco retailer density	Modified CTs (N=3846)	Categorical: A (ref), B, C, D, ungraded; all pairwise comparison	CT sociodemographic characteristics, city fixed effect	D grade was associated with higher density of tobacco retailers relative to A (RR = 1.98 [1.52, 2.60])



Table 2 (continued)

Location	Outcome(s)	Unit of analysis (sample size)	HOLC variable	Control variables	Abbreviated findings
Trangenstein et al. [78] Baltimore, MD	Clusters of four types of alcohol outlets	Census block groups (N = 537)	Categorical: B, C, D, ungraded (ref)	Population density, sociodemographic characteristics, concentrated disadvantage index, residential stability, social control or disinvestment built environment characteristics	Compared to ungraded areas, D grade was associated with higher odds of being in a general (OR = 8.82 [2.99, 25.98]), off-premise (OR = 7.32 [2.00, 26.79]), on-premise (OR = 8.07 [2.26, 28.77]), or LBD-7 (combined on/off-premise) (OR = 8.60 [2.93, 25.30]) alcohol outlet cluster
Wilson [79] Baltimore, MD; Dallas, TX; Kansas City, MO	1) LST, two summer days and 2) NDVI, two summer days	HOLC polygons	Categorical: A, B, C, D	None	C- and D-graded areas had higher median land surface temperatures than A or B in all cities ( $P < 0.01$ , Kruskal–Wallis test). Mean NDVI was lower in C- and D-graded areas compared to A- and B-graded areas in all cities

NDVI normalized difference vegetation index; OR risk ratio; RR risk ratio

**Table 3** Studies assessing the association between historical HOLC grade and subsequent (a) environmental determinants of health and (b) health-related outcomes

Location	Outcome(s)	Unit of analysis (sample size)	HOLC variable	Control variables	Abbreviated findings
Huang & Sehgal [23] Baltimore, MD	(1) Life expectancy at birth, (2) age-differentiated mortality rates, (3) teen pregnancy per 1000 female residents 15–19, (4) % of births given at term, (5) % of births with satisfactory birth weight, (6) % of births receiving 1st trimester prenatal care, (7) % children age 0–6 with elevated blood lead levels, (8) liquor outlets per 1000 residents, and (9) fast food outlets per 1000 residents	Planning board-defined community statistical areas (N = 54)	Categorical: A/B (ref), C, D	Sociodemographic characteristics	Compared to A/B-graded areas, a D grade is associated with a 5.23 [3.49, 6.98] year reduction in life expectancy. D grades were also associated with significantly higher mortality for the age groups 25–44, 45–64, and 65–84. For example, a D grade is associated with 95.47 [52.03, 138.91] additional deaths per 10,000 residents in a 5-year period. C-graded areas had 23.61 [7.97, 39.26] additional births per 1000 female residents 15–19; D, 20.36 [4.34, 36.37] additional births. C, but not D, grade was associated with reduction in % of births in which the mother received 1st trimester prenatal care (C: – 5.06 [– 8.7, – 1.43]; D: – 1.82 [– 5.54, 1.9]). D-graded areas were associated with 2.18 [1.38, 2.98] additional liquor stores per 1000 residents

Table 3 (continued)

Location	Outcome(s)	Unit of analysis (sample size)	HOLC variable	Control variables	Abbreviated findings
Li et al. [42]	11 urban areas within TX (1) Mean, minimum, and maximum LST on 1 June and 31 August Heat-related emergency department visits including (2) inpatient admissions and (3) outpatient visits	ZCTA (N not stated)	Categorical: 50% or more ZCTA area graded C or D, vs. less than 50% ZCTA area graded C or D	For outcomes 2 and 3: population aged 65 and older, non-White, Hispanic, lower income, living alone, and who does not speak English well	More redefined areas had a 3.90 °C hotter average daytime LST ( $p < 0.01$ ) and increase in the number of heat-related outpatient visits (Coef. = 0.0036 [0.0007–0.0066]) and inpatient admissions (Coef. = 0.0018 [0.0001–0.0035]) per 1000 population
Namin et al. [21]	115 urban areas nationwide (1) Tree canopy coverage (2) Lifetime cancer risk associated with air toxics (3) Average respiratory hazard index	HOLC polygon ( $N = 6556$ )	Categorical: A (ref), B, C, D	Population density (tree canopy coverage only), city random effect	D-graded areas had 16.21% less tree canopy coverage than A on average in 2011 but were more likely to experience an increase in coverage between 2001 and 2011 Compared to A-, D-graded areas had a 2.6 mean unit increase in lifetime cancer risk and 9% increase in geometric mean respiratory hazard

LST land surface temperature

## Analytic Strategy

The majority of studies utilized multivariable regression to estimate associations between HOLC grade and the outcome while controlling for potential alternative explanations, while a few studies made only bivariate or visual comparisons. Among the 20 studies using reference groups in their models, A was the most common (13 studies); others included A and B combined (3 studies), D (2), A and ungraded areas combined (1), and ungraded areas (1). Two studies compared neighboring grades (e.g., D vs. C) using propensity score matching. One study compared areas graded above vs. below 50% C or D, one compared the first and fourth quartiles of proportion graded combined A and B versus combined C and D, and three derived continuous measures of HOLC grade.

The majority of multivariate studies controlled for present-day neighborhood socioeconomic and demographic variables. Fewer considered these factors as potentially on the causal pathway between historical redlining and their present-day outcome or as effect modifiers. For example, Lynch et al. found that current CT socioeconomic status explained 85% and 87% of the association between redlining with physical and mental health, respectively [29]. And Poulson et al. found that poverty, poor educational attainment, and need for public services mediated 20% of the association between D grade and firearm incident rate [44]. Two studies utilized the Index of Concentration at the Extremes (ICE) to characterize the present-day concentration of racialized economic disadvantage and found that the association between redlining and cancer risk varied with ICE [28, 37]. Three additional studies included race [26, 27, 38], one included neighborhood social and physical environments [27], and one included 2018 lending discrimination [29], as effect modifiers.

Four studies controlled for 1940 sociodemographic variables that reflected neighborhood composition near the time of HOLC grade assignment in an effort to control for differences that pre-existed the creation of the security maps [22, 26, 45, 46]. One study additionally controlled for cumulative CT poverty from 1980 to present [30]. One study controlled for ICE for both 1940s and present day in separate models [46]. Two studies used propensity score matching to reduce unmeasured confounding by restricting their sample to be more comparable by omitting areas very unlikely to have received the same grade [26, 45].

A few studies discussed the history and context of the city or region related to the implementation of redlining and/or other racialized housing policies, while most provided no local context. While most studies focused exclusively on HOLC grades, several studies additionally considered more recent processes including foreclosure rate recovery following the 2008 Great Recession [20], present-day lending discrimination [29], blockbusting [47], and gentrification [47]. McClure et al. found that redlining was associated with higher foreclosure rates and a stronger effect of slower foreclosure recovery on self-rated health [20]. Lynch et al. found that present-day lending discrimination, and not historic HOLC grade, was associated with higher infant mortality [29]. Similarly, Sadler et al. found that redlined areas were now gentrified and offered better access to healthful food [47].

## Findings

The vast majority of studies found evidence of an association between redlining and poorer outcomes. Selected effect estimates and confidence intervals are reported in Tables 1–3. Many studies reported an association on a gradient, such that each grade moving from A to D had a higher risk for the adverse outcome, suggesting a dose–response relationship between poorer grade and adverse impact. Only one study, on healthy food access, found evidence that redlining was associated with a better outcome, which the authors suggested may be attributable to present-day gentrification [47]. Additionally, two studies found an effect of “yellow-lining” (C grade) rather than redlining (D grade) for birth-related outcomes [23, 26]. Several studies reported no association with at least one outcome, and two studies reported null findings for all outcomes, although in some cases associations were observed in unadjusted models. Although the consistency of study findings overall is striking, it is also possible that publication bias excluded null findings.

In multi-city studies, the association with a particular outcome often varied across locations. For example, Hoffman et al. found that 94% of 108 cities studied showed patterns of elevated land surface temperatures in D-graded areas compared to A-graded areas, but in some cities in the Midwest, the pattern was reversed. Further, the intra-city difference in land

surface temperature anomaly from the citywide mean, between D- as compared to A-graded areas, ranged from +7.1 to −1.5 °C [48]. In another study examining multiple health outcomes across nine cities, in St. Louis, there was little evidence of an association with redlining, while in five cities, the majority of outcomes exhibited a statistically significant association, including for outcomes for which a significant relationship was not observed in the overall sample [33].

Among outcomes examined across multiple studies, the directions of findings were generally consistent on a high level, despite variability in the specific geographies, study designs, outcome measures and strength of the association. One exception is the food environment: One study in Baltimore, MD, found that redlined areas had higher healthy food access [47], which the authors hypothesized was due to gentrification, while a nationwide study found that poorer grades were linked to poorer food environments [39]. For preterm birth, two studies found that poorer HOLC grades were associated with higher risk, while another found “yellow-lining,” i.e., higher odds for C-graded areas compared to both B-graded and D-graded areas, when using a restricted propensity score matched sample [26, 30, 40]. Findings for chronic heart disease were not consistent within and across studies [32, 33]; a possible explanation is that one study on cardiovascular health risk found that living in poorer-graded areas was associated with poorer health outcomes only for Black residents [27].

## Discussion

Evidence to date suggests that HOLC grades are associated with numerous present-day health outcomes and poorer neighborhood environmental characteristics, although associations were not completely consistent across all studies or cities examined and publication bias may have resulted in fewer studies reporting null or protective effects. The literature is difficult to synthesize because of the diversity of methodological approaches that have been taken. In an effort to inform future research in this field, we first offer a conceptual framework, followed by methodological recommendations and a discussion of limitations and gaps which future work can address.

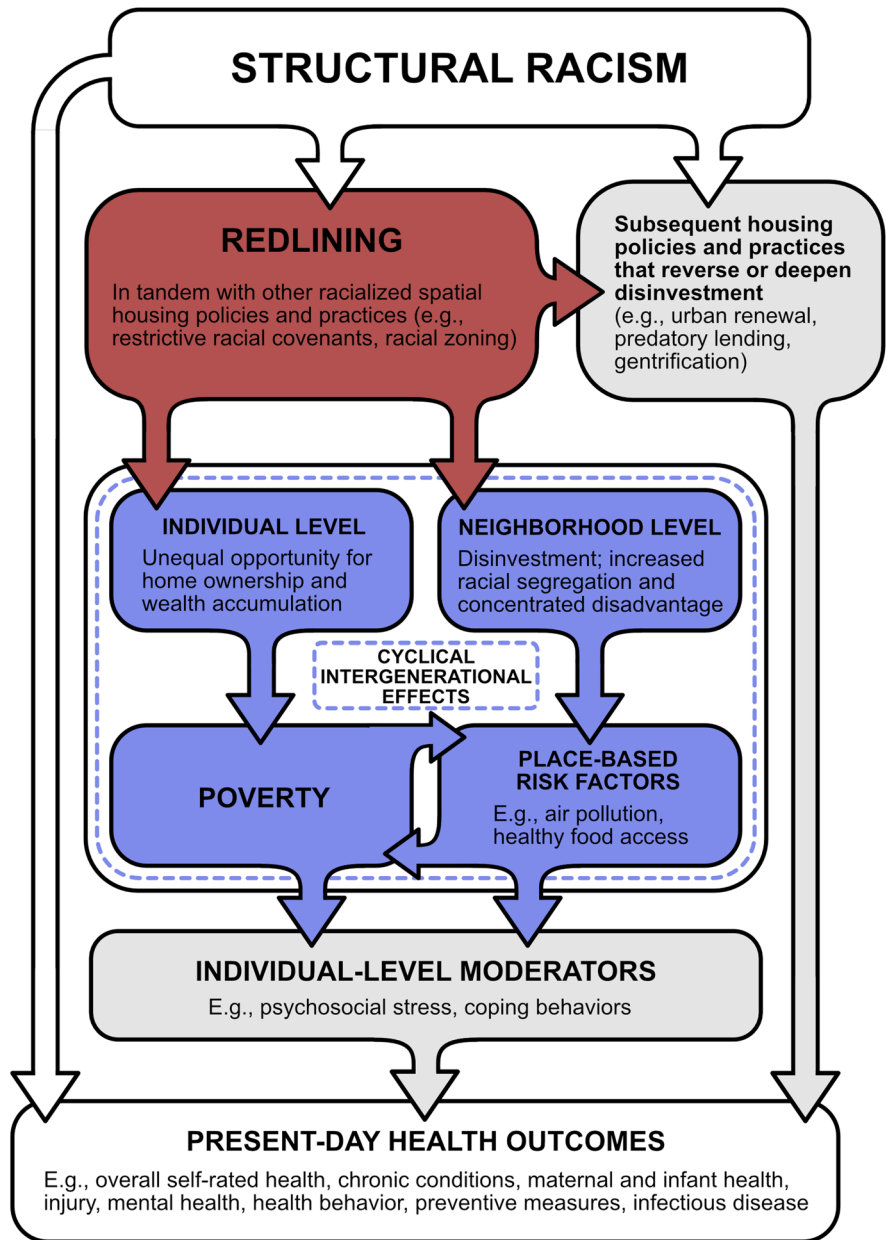
## Conceptual Framework

In Fig. 4, we propose a conceptual framework describing the relationship between historical redlining and present-day health outcomes. Our framework builds on the conceptual model proposed by Krieger et al. [30], but expands on the role of other housing policies and processes that occurred in tandem or subsequent to the creation of the HOLC security maps, differentiates between individual- and neighborhood-level pathways, and highlights the cyclical, intergenerational nature of redlining’s likely effects. With this proposed framework, we suggest that consideration of these factors is necessary in order to consider the role of redlining as embedded in a dynamic context. We also center structural racism, i.e., the systems and institutions through which societies promote racial discrimination and inequitably distribute resources, in our framework [49]. We acknowledge the pathways independent of redlining though which it may contribute present-day health inequalities — recognizing that structural racism is not a static force in the past, nor one that takes only one form, but a multifaceted phenomenon to which marginalized residents of redlined neighborhoods continue to be exposed in many ways. For example, racial discrimination has been shown to lead to chronic stress and ‘weathering’ of the body’s systems in ways that can increase individual-level susceptibility to pollutant and other hazardous exposures [50, 51].

We include additional housing policies and processes in our framework since redlining examined preexisting characteristics of a neighborhood and thus, to at least some extent, reflected neighborhood racial stratification and physical differences already in place at the time, due to other racialized housing policies such as racial zoning, restrictive covenants, and violence against people of color moving into predominantly White neighborhoods. As Lee et al. noted, HOLC grading was a “codification of segregated housing practices already developing in prior decades” [25]. Further, HOLC appraisals reflected the racialized risk assessment practices of the real estate industry that were already and separately being enacted [52, 53]. Without such pre-existing processes, redlining may not have been as effective in distributing investment and opportunity by race, as



**Fig. 4** Conceptual model of the pathway from historical redlining to present-day health outcomes



neighborhoods would not have been as segregated at the time of HOLC assessment; further, without these additional restrictions on where people could live, residents could have had greater opportunity to move away from redlined neighborhoods, attenuating the relationship between redlining and segregation. Subsequent racialized processes such as urban renewal, predatory lending, and gentrification similarly may have served to amplify or dampen the long-term effect of historical redlining on health [54]. For

example, urban renewal or gentrification might result in revalorization, reinvestment, and displacement, and thereby more favorable health outcomes in previously redlined areas than would otherwise be expected.

Second, we highlight that redlining exerted both individual- and neighborhood-level health effects. All studies we reviewed considered outcomes for residents of previously redlined neighborhoods. However, the health of individuals who previously but no longer reside in redlined neighborhoods, or their

descendants, may still be impacted. Redlining created unequal opportunity for homeownership and wealth accumulation, contributing to present-day inequalities in wealth and income — primary health determinants. Because research on the individual-level pathway is currently lacking, the literature may underestimate the true impact of redlining on present-day health.

Finally, our framework highlights the cyclical, intergenerational, and multidirectional nature of the relationship between redlining and health. The housing opportunities of one generation may impact the health of subsequent generations, and vice versa [55, 56]. Further, the relationships are multidirectional. Neighborhood risk factors and poverty can beget poor health, yet poor health can also contribute to poverty, which in turn impacts where one is able to afford to live. The interrelated nature of these variables may compound the durability of redlining's effects.

Together, these components of our framework suggest the need to consider redlining as one component in a flexible and dynamic system that produces racialized spatial disadvantage. Structural racism was not frozen in place by the implementation of redlining maps, but continues to exert effects on urban development, which can lead to shifting patterns of investment and disinvestment, inclusion and exclusion. As Lynch et al. argue, structural racism “adapts to new contexts over time to recreate the conditions that give rise to poor health for racially minoritized populations” [29]. Such adaptation could have occurred in variable forms across cities, even while upholding hierarchical relations between race and space. Meanwhile, whiteness is inherently unstable, given its socially constructed nature, with the boundaries of racialized groups and racial meanings constantly shifting across time in the USA, although a hierarchy topped by whiteness persists [57, 58].

One implication is that the lack of association between redlining and an outcome in a redlined neighborhood may not mean that redlining did not exert a harmful effect, but rather, that subsequent manifestations of structural racism have subsequently altered that area and pushed marginalized residents and disinvestment elsewhere — maintaining the underlying relationship between structural racism, place, and health. Indeed, redlining could influence such subsequent shifts; the geographer Neil Smith argued that prior redlining created conditions for profitable subsequent revalorization, gentrification, and

displacement [59]. Another implication is that redlining's effects may play out differently across racialized groups and regional contexts. This could help explain why the presence and size of associations between redlining and health-related outcomes varies across and even within the studies we reviewed. The fluid boundaries of whiteness have altered since the time of redlining, and not all groups viewed unfavorably in neighborhood appraisals continue to experience the same degree of disadvantage today. While Jewish and Southern and Eastern European residents, for example, were often described as undesirable by HOLC assessors [7], they have since been assimilated into the American definition of whiteness [58, 60]. Therefore, the trajectory of redlining's impact on these populations may have changed, interrupting the relationship with present-day advantage. These examples demonstrate how a more explicit conceptual framework that accounts for the dynamism of structural racism may help reveal more precise associations between redlining and present-day outcomes as well as the mechanisms by which redlining impacted health over time, and for which populations.

### Methodological Recommendations

Future studies would benefit from clearly articulating a conceptual framework and discussing how it informed their analytic choices, including whether variables included in the analysis are conceived as confounders, mediators, or modifiers of associations between redlining and the outcomes.

The conceptual framework can also inform analytical choices for assigning and comparing HOLC grades. For example, comparing A- vs. D-graded areas is appropriate if the goal is to describe the overall scale of inequality. However, comparisons of neighboring grades (e.g., D vs. C) are probably more useful in isolating subtle associations with HOLC grade assignment, since A and D graded areas likely already different substantially prior to the creation of HOLC maps. Where feasible, descriptive statistics for all grades as well as associations with intermediate B and C grades should be reported in order to demonstrate whether a dose-exposure gradient relationship exists and facilitate comparisons across studies. Studies also should consider including ungraded areas and address why inclusion of such areas is or is not appropriate based on the study question, conceptual framework, and city's history.

The possibility of uncontrolled confounding can also be revealed via a conceptual framework and/or DAG [61]. Uncontrolled confounding might arise when pre-existing differences between neighborhoods partially explain relationships between grade and subsequent outcomes. Methods such as propensity-score analysis or difference-in-differences approaches [62] have been applied to attempt to control for such pre-existing differences at the time of HOLC designations, but this was relatively rare in the literature.

Finally, several studies we reviewed revealed city-specific difference in associations between redlining and outcomes that are ripe for further study to better understand contextual differences [26, 32, 33, 63]. Researchers examining multiple cities should present disaggregated city-specific results to identify such heterogeneity in effects across cities. One contributing factor may be that HOLC relied to a large extent on input from local finance and real estate informants in grading neighborhoods, which allowed idiosyncrasy to enter into evaluation and could generate variability in rating criteria across cities; for example, a Black neighborhood received an “A” rating in Savannah, GA, at local realtors’ suggestion [5]. Another could be that neighborhood trajectories may have changed since redlining, and as such, studies of a single city or region can benefit from discussion of local historical context. For example, Lynch et al. examined present-day disinvestment in addition to redlining, observing that “subsequent anti-Black disinvestment in the decades after HOLC residential security maps shifted with Black migration patterns,” e.g., displacement from urban renewal [29].

### Limitations of HOLC Maps as a Measure of Redlining

A key concept for researchers to consider moving forward is the precise utility of HOLC grades as a proxy for redlining and its relationship to pathways of interest. Researchers typically framed HOLC as a direct cause of disinvestment. However, there is evidence to suggest that HOLC maps were not major determinants of access to mortgage loans. HOLC maps were made after HOLC had already made the vast majority of its emergency loans [5]. Further, the agency’s lending patterns did not correlate with grades: substantial proportions of HOLC loans were made in what would become C- and D-graded

areas, and Black homeowners received assistance proportional to their share of the homeowner population [64, 65]. The FHA, which made its own mortgage risk maps, accounted for a far greater proportion of home loan guarantees and backed mortgages for Black-occupied single-family properties at much disproportionately lower rates than HOLC [64, 66]. Xu’s recent study comparing the HOLC and FHA maps of Chicago found that although there is significant overlap in grades, there are also differences, e.g., most tracts graded A and B by the FHA were graded C by HOLC. She also found that the FHA’s maps are more closely associated with subsequent detrimental effects on home values and homeownership rates [67]. Further, Fishback et al. found that HOLC was much more likely to make loans in what would become its C- and D-rated areas than the FHA [66]. Nevertheless, HOLC lending practices still reinforced segregation by supporting already-existing patterns with its loans and through discrimination in reselling foreclosed properties, and areas redlined by HOLC received poorer mortgage terms [64, 65]. We feel that conceptual frameworks and interpretations of findings should not overstate the causal role of HOLC maps in isolation. While direct impacts of the maps are possible, they may be limited relative to how they are often understood. Instead, HOLC maps may be most usefully conceptualized as reflections of beliefs about race, place, and value that can serve as a proxy — rather than a direct measure — of investment decisions by a diverse set of actors.

### Gaps and Suggested Future Directions

Research on redlining, neighborhood environments, and health is still nascent, and there are a number of opportunities for further research. Our suggestions span two key gaps: widening the breadth of outcomes studied and illuminating the relationship between redlining and health with greater nuance and precision.

Given the relative novelty of research on redlining and health, a much wider range of outcomes merit attention. With regard to health-related outcomes, research has not yet examined, for example, infectious disease (with the exception of Covid-19); only two studies assess mental health and only for a general indicator. Yet the literature on neighborhood determinants of health suggests these, and many other,

outcomes are linked to neighborhood characteristics [68, 69]. Likewise, many additional environmental variables associated with health disparities could be examined to strengthen the evidence base, such as walkability, flood risk, and point sources of pollution such as waste processing facilities or highways, and social characteristics (e.g., social cohesion) [70]. To date, research has primarily considered health determinants and health outcomes separately; whereas future work could jointly consider both in order to better illuminate pathways and points of intervention. Greater representativeness of the geographical distribution of redlined cities could be achieved as most studies cluster along the coasts and the eastern Midwest.

Longitudinal studies may be challenging given the paucity of historical health data, but could help reveal the changing trajectory of redlining's effects and interactions with other policies over time. For example, prior work suggests that the association between HOLC grades and subsequent gaps in home values and rates of homeownership peaked around the 1970s, and then narrowed [8]. Complementing identification of such changes over time, researchers should consider policies that revalorized or caused further disinvestment in previously redlined areas. For example, if previously redlined neighborhoods in the study area are more often subject to recent gentrification, gentrification could ideally be considered in the analysis. Longitudinal studies could also follow individuals or families who moved in or out of previously redlined areas over time and investigate the extent of redlining's intergenerational influence on the health of individuals who do not currently live in previously redlined areas. This could elucidate when in the lifecourse, the impacts of exposure to redlined neighborhoods are greatest (e.g., as a child vs. adult) and the influence of the amount of time lived in the neighborhood.

Despite the racialized nature of HOLC grade assignments, the studies we reviewed to date rarely stratified results by race even when such information was available. Such disaggregation could help reveal the extent to which the enduring legacy of redlining differs across racialized groups within the same neighborhood and contributes to racial health disparities. Studies could also consider assessing whether redlining's association with present-day outcomes is affected by the neighborhood's racial composition at

time of redlining, e.g., whether it differs in redlined neighborhoods whose residents were primarily Black vs. those whose residents were primarily from immigrant ethnic groups.

HOLC maps may be an imperfect proxy for the full range of direct effects of redlining, and as such, redlining maps created by other actors, particularly the FHA, should be identified and used to assess the relationship with redlining and present-day health-related outcomes [67]. When HOLC maps are used, researchers should more clearly state the relationship between HOLC maps, the construct of redlining, and relevant pathways to health. Comparing the relative abilities of FHA and HOLC maps to predict health-related outcomes could help assess the value of HOLC maps as a redlining indicator.

## Conclusion

Evidence to date suggests that HOLC grades, as an indicator of historical spatialized structural racism, are indeed associated with a diverse set of present-day neighborhood environmental and health outcomes. Future research to strengthen the evidence base will benefit from a clearly articulated conceptual framework, careful consideration of confounding, incorporation of longitudinal analysis, examination of effect modification by race/ethnicity, consideration of individual- in addition to neighborhood-level pathways as well as local historical context, and assessments of FHA maps and other possible operationalizations of redlining practices. Interrogating the role of practices like redlining in shaping subsequent community health can move research beyond mere documentation of racialized health disparities towards better understanding of the role of governmental decision-making in driving health disparities and possible points of intervention in the processes through which structural racism creates health disparities [71–73] — informing efforts to appropriately targeted reparative policies, which numerous policymakers have proposed [74, 75].

It is important, however, that further research not come at the expense of action. Focusing on identifying a precise causal impact attributable specifically to HOLC maps, as Hill observes, “overdetermines contemporary outcomes of past practices while missing the suite of policies and practices that informed spatial racism at that time and today.” Rather, analyzing

associations between HOLC maps and health may be most useful to the extent that they illustrate the underlying construct of spatial racism [76]. There is sufficient evidence that place-based disparities in opportunities for good health have been shaped by a suite of racialized housing policies. These disparities merit urgent action, whether or not they precisely align with historically redlined areas [75]. Understanding the relationship between redlining and health is thus not important only for its individual, discrete power to predict present-day outcomes. Redlining is one brick in the edifice of structural racism, providing one example of its harmful and persistent effects and pointing us to the need for action to address disparities wherever they take place today.

**Acknowledgements** The authors gratefully acknowledge the contributions of Sherlock Li for assistance in producing Fig. 3 and Chris Vacchio for assistance in producing Fig. 4.

**Funding** DH was supported by the NIEHS Center for Environmental Health in Northern Manhattan (P30 ES009089) where she serves as the co-Director of Community Engagement Core. LJC was supported by the JPB Environmental Health Fellowship and Jonathan and Karin Fielding Presidential Chair in Health Equity.

## References

- Rothstein R. *The color of law : a forgotten history of how our government segregated America*. New York ; London: Liveright Publishing Corporation, a division of W. W. Norton & Company; 2018.
- Faber JW. We built this: consequences of new deal era intervention in America's racial geography. *Am Sociol Rev.* 2020;85(5):739–75. <https://doi.org/10.1177/0003122420948464>.
- Woods LL, Shaw-Ridley M, Woods CA. Can health equity coexist with housing inequalities? A contemporary issue in historical context. *Health Promot Pract.* 2014;15(4):476–82.
- Greer J. The home owners' loan corporation and the development of the residential security maps. *J Urban Hist.* 2013;39(2):275–96. <https://doi.org/10.1177/0096144212436724>.
- Michney TM. How the city survey's redlining maps were made: a closer look at HOLC's mortgagee rehabilitation division. *J Plan Hist.* Published online May 7, 2021:15385132211013360. <https://doi.org/10.1177/15385132211013361>
- Markley S. Tabulating HOLC area description sheet data. Published online September 15, 2021. Accessed September 30, 2021. <https://osf.io/qytj8/>
- Nelson RK, Winling L, Marciano R, Connolly N. Mapping inequality: redlining in new deal America. Nelson RK, Ayers EL, eds. Accessed October 5, 2020. <https://dsl.richmond.edu/panorama/redlining/>
- Aaronson D, Hartley D, Mazumder B. The effects of the 1930s HOLC "Redlining" maps. *Am Econ J Econ Policy.* 2021;13(4):355–92. <https://doi.org/10.1257/pol.20190414>.
- Woods LL. The Federal Home Loan Bank Board, redlining, and the national proliferation of racial lending discrimination, 1921–1950. *J Urban Hist.* 2012;38(6):1036–59.
- Rutan DQ, Glass MR. The lingering effects of neighborhood appraisal: evaluating redlining's legacy in Pittsburgh. *Prof Geogr.* 2018;70(3):339–49. <https://doi.org/10.1080/00330124.2017.1371610>.
- Park KA, Quercia RG. Who lends beyond the red line? The Community Reinvestment Act and the Legacy of Redlining. *Hous Policy Debate.* 2019;30(1):4–26. <https://doi.org/10.1080/10511482.2019.1665839>.
- Faber J. Contemporary echoes of segregationist policy: spatial marking and the persistence of inequality. *Urban Stud.* 2021;58(5):1067–86. <https://doi.org/10.1177/0042098020947341>.
- Connolly NDB, Winling L, Nelson RK, Marciano R. Mapping inequality : 'Big data' meets social history in the story of redlining. In: *The Routledge Companion to Spatial History.* ; 2018. <https://doi.org/10.4324/9781315099781-29>
- Lee EK, Donley G, Ciesielski TH, et al. Health outcomes in redlined versus non-redlined neighborhoods: a systematic review and meta-analysis. *Soc Sci Med.* Published online December 31, 2021:114696. <https://doi.org/10.1016/j.socscimed.2021.114696>
- Munn Z, Peters MDJ, Stern C, Tufanaru C, McArthur A, Aromataris E. Systematic review or scoping review? Guidance for authors when choosing between a systematic or scoping review approach. *BMC Med Res Methodol.* 2018;18(1):143. <https://doi.org/10.1186/s12874-018-0611-x>.
- Peters MDJ, Godfrey CM, Khalil H, McInerney P, Parker D, Soares CB. Guidance for conducting systematic scoping reviews. *JBIM Evid Implement.* 2015;13(3):141–6. <https://doi.org/10.1097/XEB.0000000000000050>.
- Arksey H, O'Malley L. Scoping studies: towards a methodological framework. *Int J Soc Res Methodol Theory Pract.* 2005;8(1):19–32. <https://doi.org/10.1080/1364557032000119616>.
- Levac D, Colquhoun H, O'Brien KK. Scoping studies: advancing the methodology. *Implement Sci.* 2010;5(1):69. <https://doi.org/10.1186/1748-5908-5-69>.
- Tricco AC, Lillie E, Zarin W, et al. PRISMA extension for scoping reviews (PRISMA-ScR): checklist and explanation. *Ann Intern Med.* 2018;169(7):467–73. <https://doi.org/10.7326/M18-0850>.
- McClure E, Feinstein L, Cordoba E, et al. The legacy of redlining in the effect of foreclosures on Detroit residents' self-rated health. *Health Place.* 2019;55:9–19. <https://doi.org/10.1016/j.healthplace.2018.10.004>.
- Namin S, Xu W, Zhou Y, Beyer K. The legacy of the Home Owners' Loan Corporation and the political ecology of urban trees and air pollution in the United States. *Soc Sci Med.* 2020;246: 112758. <https://doi.org/10.1016/j.socscimed.2019.112758>.



22. Jacoby SF, Dong B, Beard JH, Wiebe DJ, Morrison CN. The enduring impact of historical and structural racism on urban violence in Philadelphia. *Soc Sci Med*. 2018;199:87–95. <https://doi.org/10.1016/j.socscimed.2017.05.038>.
23. Huang SJ, Sehgal NJ. Association of historic redlining and present-day health in Baltimore. *PLoS ONE*. 2022;17(1): e0261028. <https://doi.org/10.1371/journal.pone.0261028>.
24. Bennis M, Ruther M, Nash N, Bozeman M, Harbrecht B, Miller K. The impact of historical racism on modern gun violence: redlining in the city of Louisville. *KY Injury*. 2020;51(10):2192–8. <https://doi.org/10.1016/j.injury.2020.06.042>.
25. Lee JP, Ponicki W, Mair C, Gruenewald P, Ghanem L. What explains the concentration of off-premise alcohol outlets in Black neighborhoods? *SSM - Popul Health*. 2020;12: 100669. <https://doi.org/10.1016/j.ssmph.2020.100669>.
26. Nardone AL, Casey JA, Rudolph KE, Karasek D, Mujahid M, Morello-Frosch R. Associations between historical redlining and birth outcomes from 2006 through 2015 in California. *PLoS ONE*. 2020;15(8): e0237241. <https://doi.org/10.1371/journal.pone.0237241>.
27. Mujahid MS, Gao X, Tabb LP, Morris C, Lewis TT. Historical redlining and cardiovascular health: the multi-ethnic study of atherosclerosis. *Proc Natl Acad Sci*. 2021;118(51). <https://doi.org/10.1073/pnas.2110986118>
28. Wright E, Waterman PD, Testa C, Chen JT, Krieger N. Breast cancer incidence, hormone receptor status, historical redlining, and current neighborhood characteristics in Massachusetts, 2005–2015. *JNCI Cancer Spectr*. 2022;6(2). <https://doi.org/10.1093/jncics/pkac016>
29. Lynch EE, Malcoe LH, Laurent SE, Richardson J, Mitchell BC, Meier HCS. The legacy of structural racism: associations between historic redlining, current mortgage lending, and health. *SSM - Popul Health*. 2021;14: 100793. <https://doi.org/10.1016/j.ssmph.2021.100793>.
30. Krieger N, Van Wye G, Huynh M, et al. Structural racism, historical redlining, and risk of preterm birth in New York City, 2013–2017. *Am J Public Health*. 2020;110(7):1046–53. <https://doi.org/10.2105/AJPH.2020.305656>.
31. Li M, Yuan F. Historical redlining and food environments: a study of 102 urban areas in the United States. *Health Place*. 2022;75: 102775. <https://doi.org/10.1016/j.healthplace.2022.102775>.
32. White AG, Guikema SD, Logan TM. Urban population characteristics and their correlation with historic discriminatory housing practices. *Appl Geogr*. 2021;132: 102445. <https://doi.org/10.1016/j.apgeog.2021.102445>.
33. Nardone A, Chiang J, Corburn J. Historic redlining and urban health today in U.S. Cities. *Environ Justice*. 2020;13(4):109–119. <https://doi.org/10.1089/env.2020.0011>
34. Huggins JC. A cartographic perspective on the correlation between redlining and public health in Austin, Texas-1951. *Cityscape*. 2017;19(2):267–80.
35. Schwartz E, Onnen N, Craigmile PF, Roberts ME. The legacy of redlining: associations between historical neighborhood mapping and contemporary tobacco retailer density in Ohio. *Health Place*. 2021;68: 102529. <https://doi.org/10.1016/j.healthplace.2021.102529>.
36. Nardone A, Casey JA, Morello-Frosch R, Mujahid M, Balmes JR, Thakur N. Associations between historical residential redlining and current age-adjusted rates of emergency department visits due to asthma across eight cities in California: an ecological study. *Lancet Planet Health*. 2020;4(1):e24–31. [https://doi.org/10.1016/S2542-5196\(19\)30241-4](https://doi.org/10.1016/S2542-5196(19)30241-4).
37. Krieger N, Wright E, Chen JT, Waterman PD, Huntley ER, Arcaya M. Cancer stage at diagnosis, historical redlining, and current neighborhood characteristics: breast, cervical, lung, and colorectal cancer, Massachusetts, 2001–2015. *Am J Epidemiol*. 189(10):1065–1075. <https://doi.org/10.1093/aje/kwaa045>
38. Diaz A, O'Reggio R, Norman M, Thumma JR, Dimick JB, Ibrahim AM. Association of historic housing policy, modern day neighborhood deprivation and outcomes after inpatient hospitalization. *Ann Surg*. 2021;274:985–91. <https://doi.org/10.1097/SLA.00000000000005195>.
39. Li M, Yuan F. Historical redlining and resident exposure to COVID-19: a study of New York City. *Race Soc Probl*. Published online June 18, 2021. <https://doi.org/10.1007/s12552-021-09338-z>
40. Hollenbach SJ, Thornburg LL, Glantz JC, Hill E. Associations between historically redlined districts and racial disparities in current obstetric outcomes. *JAMA Netw Open*. 2021;4(9): e2126707. <https://doi.org/10.1001/jamanetworkopen.2021.26707>.
41. Saverino KC, Routman E, Lookingbill TR, Eanes AM, Hoffman JS, Bao R. Thermal inequity in Richmond, VA: the effect of an unjust evolution of the urban landscape on urban heat islands. *Sustainability*. 2021;13(3):1511. <https://doi.org/10.3390/su13031511>.
42. Li D, Newman GD, Wilson B, Zhang Y, Brown RD. Modeling the relationships between historical redlining, urban heat, and heat-related emergency department visits: an examination of 11 Texas cities. *Environ Plan B Urban Anal City Sci*. Published online August 23, 2021. <https://doi.org/10.1177/23998083211039854>
43. Lane HM, Morello-Frosch R, Marshall JD, Apte JS. Historical redlining is associated with present-day air pollution disparities in U.S. cities. *Environ Sci Technol Lett*. 2022;9(4):345–350. <https://doi.org/10.1021/acs.estlett.1c01012>
44. Poulson M, Neufeld MY, Dechert T, Allee L, Kenzik KM. Historic redlining, structural racism, and firearm violence: a structural equation modeling approach. *Lancet Reg Health - Am*. 2021;3: 100052. <https://doi.org/10.1016/j.lana.2021.100052>.
45. Nardone A, Rudolph KE, Morello-Frosch R, Casey JA. Redlines and Greenspace: the relationship between historical redlining and 2010 greenspace across the United States. *Environ Health Perspect*. 2021;129(1): 017006. <https://doi.org/10.1289/EHP7495>.
46. Schinasi LH, Kanungo C, Christman Z, Barber S, Tabb L, Headen I. Associations between historical redlining and present-day heat vulnerability housing and land cover characteristics in Philadelphia. *PA J Urban Health*. 2022;99:134–45. <https://doi.org/10.1007/s11524-021-00602-6>.
47. Sadler RC, Bilal U, Furr-Holden CD. Linking historical discriminatory housing patterns to the contemporary food

- environment in Baltimore. *Spat Spatio-Temporal Epidemiol.* 2021;36: 100387. <https://doi.org/10.1016/j.sste.2020.100387>.
48. Hoffman JS, Shandas V, Pendleton N. The effects of historical housing policies on resident exposure to intra-urban heat: a study of 108 US urban areas. *Climate.* 2020;8(1):12. <https://doi.org/10.3390/cli8010012>.
  49. Bailey ZD, Krieger N, Agénor M, Graves J, Linos N, Bassett MT. Structural racism and health inequities in the USA: evidence and interventions. *The Lancet.* 2017;389(10077):1453–63.
  50. Geronimus A, Hicken M, Keene D, Bound J. “Weathering” and age patterns of allostatic load scores among Blacks and Whites in the United States. *Am J Public Health Wash.* 2006;96(5):826–33.
  51. Gee GC, Payne-Sturges DC. Environmental health disparities: a framework integrating psychosocial and environmental concepts. *Environ Health Perspect.* 2004;112(17):1645–53. <https://doi.org/10.1289/ehp.7074>.
  52. Imbroscio D. Race matters (even more than you already think): racism, housing, and the limits of *The Color of Law*. *J Race Ethn City.* 2020;2(1):29–53. <https://doi.org/10.1080/26884674.2020.1825023>.
  53. Crossney KB, Bartelt DW. The legacy of the home owners’ loan corporation. *Hous Policy Debate.* 2005;16(3–4):547–74. <https://doi.org/10.1080/10511482.2005.9521555>.
  54. Fullilove MT, Wallace R. Serial forced displacement in American cities, 1916–2010. *J Urban Health.* 2011;88(3):381–9. <https://doi.org/10.1007/s11524-011-9585-2>.
  55. Saegert S, Evans GW. Poverty, housing niches, and health in the United States. *J Soc Issues.* 2003;59(3):569–89. <https://doi.org/10.1111/1540-4560.00078>.
  56. Saegert S, Fields D, Libman K. Mortgage foreclosure and health disparities: serial displacement as asset extraction in African American populations. *J Urban Health.* 2011;88(3):390–402. <https://doi.org/10.1007/s11524-011-9584-3>.
  57. Haney-López I. *White by law : the legal construction of race*. New York: New York University Press; 1996.
  58. Omi M, Winant H. *Racial formation in the United States*. 2nd ed. New York: Routledge; 2014.
  59. Smith N. *The new urban frontier: gentrification and the Revanchist City*. 1st Edition. New York: Routledge; 1996.
  60. Roediger D. *Working toward Whiteness*. New York: Basic Books; 2018.
  61. Shrier I, Platt RW. Reducing bias through directed acyclic graphs. *BMC Med Res Methodol.* 2008;8(1):70. <https://doi.org/10.1186/1471-2288-8-70>.
  62. Hynsjö DM, Perdoni L. *The effects of federal “Redlining” maps: a novel estimation strategy.*; 2021.
  63. Locke DH, Hall B, Grove JM, et al. Residential housing segregation and urban tree canopy in 37 US Cities. *Npj Urban Sustain.* 2021;1. <https://doi.org/10.1038/s42949-021-00022-0>
  64. Michney TM, Winling L. New perspectives on new deal housing policy: explicating and mapping HOLC loans to African Americans. *J Urban Hist.* 2020;46(1):150–80. <https://doi.org/10.1177/0096144218819429>.
  65. Hillier AE. Redlining and the home owners’ loan corporation. *J Urban Hist.* 2003;29(4):394–420. <https://doi.org/10.1177/0096144203029004002>.
  66. Fishback PV, Rose J, Snowden KA, Storrs T. *New evidence on redlining by federal housing programs in the 1930s*. National Bureau of Economic Research; 2021. <https://doi.org/10.3386/w29244>
  67. Xu W. Legacies of institutionalized redlining: a comparison between speculative and implemented mortgage risk maps in Chicago, Illinois. *Hous Policy Debate*. Published online February 25, 2021:1–26. <https://doi.org/10.1080/10511482.2020.1858924>
  68. Maas B, Fairbairn N, Kerr T, Li K, Montaner JSG, Wood E. Neighborhood and HIV infection among IDU: place of residence independently predicts HIV infection among a cohort of injection drug users. *Health Place.* 2007;13(2):432–9. <https://doi.org/10.1016/j.healthplace.2006.05.005>.
  69. Diez Roux AV, Mair C. Neighborhoods and health. *Ann N Y Acad Sci.* 2010;1186(1):125–45. <https://doi.org/10.1111/j.1749-6632.2009.05333.x>.
  70. Swope CB, Hernández D. Housing as a determinant of health equity: a conceptual model. *Soc Sci Med.* 2019;243. <https://doi.org/10.1016/j.socscimed.2019.112571>
  71. Jones CP. Invited commentary: “Race”, racism, and the practice of epidemiology. *Am J Epidemiol.* 2001;154(4):299–304. <https://doi.org/10.1093/aje/154.4.299>.
  72. Jee-Lyn García J, Sharif MZ. Black Lives Matter: a commentary on racism and public health. *Am J Public Health.* 2015;105(8):e27–30. <https://doi.org/10.2105/AJPH.2015.302706>.
  73. Hardeman RR, Murphy KA, Karbeah J, Kozhimannil KB. Naming institutionalized racism in the public health literature: a systematic literature review. *Public Health Rep.* 2018;133(3):240–9. <https://doi.org/10.1177/0033354918760574>.
  74. Who will presidential candidates’ redlining plans actually benefit? *Bloomberg.com*. <https://www.bloomberg.com/news/articles/2019-10-18/inside-2020-candidates-plans-to-address-redlining>. Published October 18, 2019. Accessed June 9, 2021.
  75. Perry AM, Harshbarger D. America’s formerly redlined neighborhoods have changed, and so must solutions to rectify them. Brookings. Published October 14, 2019. Accessed May 11, 2021. <https://www.brookings.edu/research/american-cas-formerly-redlines-areas-changed-so-must-solutions/>
  76. Hill AB. Before redlining and beyond. *Metropolitics*. Published November 2, 2021. Accessed November 8, 2021. <https://metropolitics.org/Before-Redlining-and-Beyond.html>
  77. Nowak DJ, Ellis A, Greenfield EJ. The disparity in tree cover and ecosystem service values among redlining classes in the United States. *Landscape and Urban Planning.* 2022;221.
  78. Trangenstein PJ, Gray C, Rossheim ME, Sadler R, Jernigan DH. Alcohol outlet clusters and population disparities. *J Urban Health.* 2020;97(1):123–36. <https://doi.org/10.1007/s11524-019-00372-2>.
  79. Wilson B. Urban Heat Management and the Legacy of Redlining. *Journal of the American Planning Association.* 2020;86(4):443–57. <https://doi.org/10.1080/01944363.2020.1759127>.