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### Community Resilience: A Dynamic Model for Public Health 3.0.

Wendy Ellis

William H. Dietz

Kuan-Lung Daniel Chen

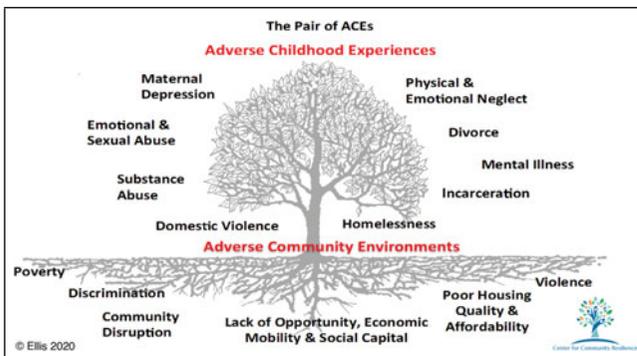
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**FIGURE 1** The Pair of ACEs Tree<sup>a</sup>

Abbreviation: ACE, adverse childhood experience.

<sup>a</sup>The “leaves” on the tree represent the symptoms of adverse childhood experiences that are easily recognized in clinical, educational, and social service settings, such as a child well visit or a preschool classroom. The tree is planted in soil that is steeped in structural racism, robbing it of nutrients necessary to support a thriving community. Adverse community environments, such as lack of affordable and safe housing, community violence, racism and discrimination, and limited access to social and economic mobility, create a vicious cycle that undermines the resilience of the tree (community). Used with permission. This figure is available in color online ([www.JPHMP.com](http://www.JPHMP.com)).

how adverse childhood experiences and adverse community environments—the “pair of ACEs”—produce complex trauma felt at the individual, family, and population levels (Figure 1).<sup>10</sup>

As we explore in this article, the influence of structural racism on housing, education, law enforcement, and criminal justice impairs CR. Many of the nation’s poor and communities of color live in areas of concentrated poverty, violence, and other community-based stressors not by choice, but rather by design—the cumulative result of social and criminal policies enacted over the course of our country’s history to enforce structural racism. The wealth gap between Black and White households is 10-fold—White families have on average a net worth of \$171 000 compared with \$17 000 for Black families.<sup>11</sup> The source of the racial wealth gap has its roots in New Deal housing programs that limited where and whether families of color could rent or purchase homes.<sup>12</sup> Gaps in accumulated wealth are just one measure of systemic racism in the United States that has efficiently produced disparities in poverty, educational attainment, and health that can be traced to the provision of “separate and unequal” services, benefits, and infrastructure based on race and place. Research connects the racial wealth gap (poverty) to the Black-White educational achievement gap.<sup>3</sup> While our housing and education policies contribute to race-based disparities, the nation’s criminal justice policies maintain and often exacerbate racial inequality by disproportionately incarcerating young Black men, thereby further excluding them from economic mobility upon release.<sup>13</sup> The cumulative impact of systemic racism

across housing, education, and criminal justice results in Black families and communities of color having less access to economic and social resources to support health and well-being, which contributes to the 6-year gap in life expectancy between non-Hispanic Whites and non-Hispanic Blacks.<sup>14</sup>

## Public Health Theory: Community Resilience

Individual resilience, defined by a person’s ability to respond and recover from adversity, requires equitable community environments with access to buffers and supports that foster CR—the ability to “bounce back.” As illustrated by the COVID-19 pandemic, communities long experiencing chronic adversities produced by structural racism lack equitable access to economic mobility, health care, quality educational supports, and safe community environments and suffer the greatest when facing acute shocks due to limited ability to respond and recover.

Because multiple and complex interacting factors influence community environments, a systems approach can provide a unique tool for public health leaders to understand the many leverage points for building CR and to isolate specific policy drivers that contribute to inequitable community environments.

Varying definitions of CR exist across multiple disciplines, including disaster preparedness and planning in the face of climate change.<sup>15</sup> Key elements that help communities bounce back after acute shocks are also indicators of a community’s day-to-day vitality, cohesion, and social capital.<sup>16</sup> We define CR as follows: (1) the sustained ability of community systems to prepare for, withstand, and recover from acute shocks while addressing and preventing the chronic adverse effects of structural racism,<sup>17</sup> and (2) a community’s ability to cope, strive, and be supported through equitable access to buffers that address and relieve sources of chronic stress and acute adversity.

## Community Resilience as a Public Health 3.0 Strategy

Our CR model provides a framework for local public health to monitor and evaluate its practice and lead initiatives aimed at addressing systemic inequities. Public Health 3.0 is defined as “a model in which leaders serve as chief health strategists (CHS), partnering across multiple sectors and leveraging data and resources to address social, environmental, and economic conditions that affect health and health equity.”<sup>18(p1)</sup> A key role of the CHS is to work across sectors to drive initiatives that address the upstream determinants of health, many of which are rooted in structural racism.

The CR model provides a system dynamics framework to define and measure key indices produced by systems and experienced by communities to measure progress toward equity by identifying and undoing specific outputs of structural racism (ie, homelessness, graduation rates, and arrest rates). To improve health and well-being, our framework identifies measures and design initiatives that address social determinants, ACEs, and the adverse community environments that structural racism produces.

Our model focuses on the policies and practices within housing, public education, law enforcement, and criminal justice that moderate resilience for families and communities by shaping community characteristics and the nature of resources available to promote optimal health and well-being. The variability of resources across zip codes within a region emphasizes that CR is relational, place-based, and variable, depending on the demographic makeup of residents, historical patterns and structures of place-based racism and discrimination, jurisdictional policy, and investment priorities.

Congruent with the CR literature, we do not isolate health care or local public health as separate systems within this model.<sup>19</sup> Local public health systems and the delivery of health care are influencers that provide supports to promote health, well-being, and resilience and are key indicators within the systems in our model.

## Methods

### *Review of the literature*

To clarify the concept of CR, we initially searched the literature in public health, medicine, psychology, early childhood development, neurobiology, and disaster preparedness and response using PubMed, PsycINFO, and Social Abstracts. Initial search terms used were “resilience” with associated terms such as “community resilience,” “childhood resilience,” “community adversity,” and “childhood adversity.” As the scope widened to include a greater understanding of community adversity, search terms were added to include indicators related to housing, schools, and juvenile justice, such as “housing discrimination,” “racial bias in home lending,” “school discipline,” “school to prison pipeline,” “sentencing mandates,” “juvenile justice reform,” “juvenile delinquency,” “community policing,” and “parental incarceration.” All articles found through the online search process were reviewed for relevance. Sources were included if they were (1) in English; (2) peer-reviewed; (3) government reports or documentation of proceedings; and (4) focused on multiple components of resilience. The

search expanded in a snowball fashion to include contemporary accounts of structural racism that promoted synergistic negative effects (vicious cycles) within communities.

The analyses examined patterns associated with ACEs, the historical underpinnings of adverse community environments (antecedents), and resilience (response). The individual, family, or community context in which resilience was described was noted.

On the basis of the literature, we mapped domains (systems) for our model of CR, including a rationale for each domain. Using these findings, we formalized a theory of CR that considers the systems of housing, public schools, law enforcement, and criminal justice.

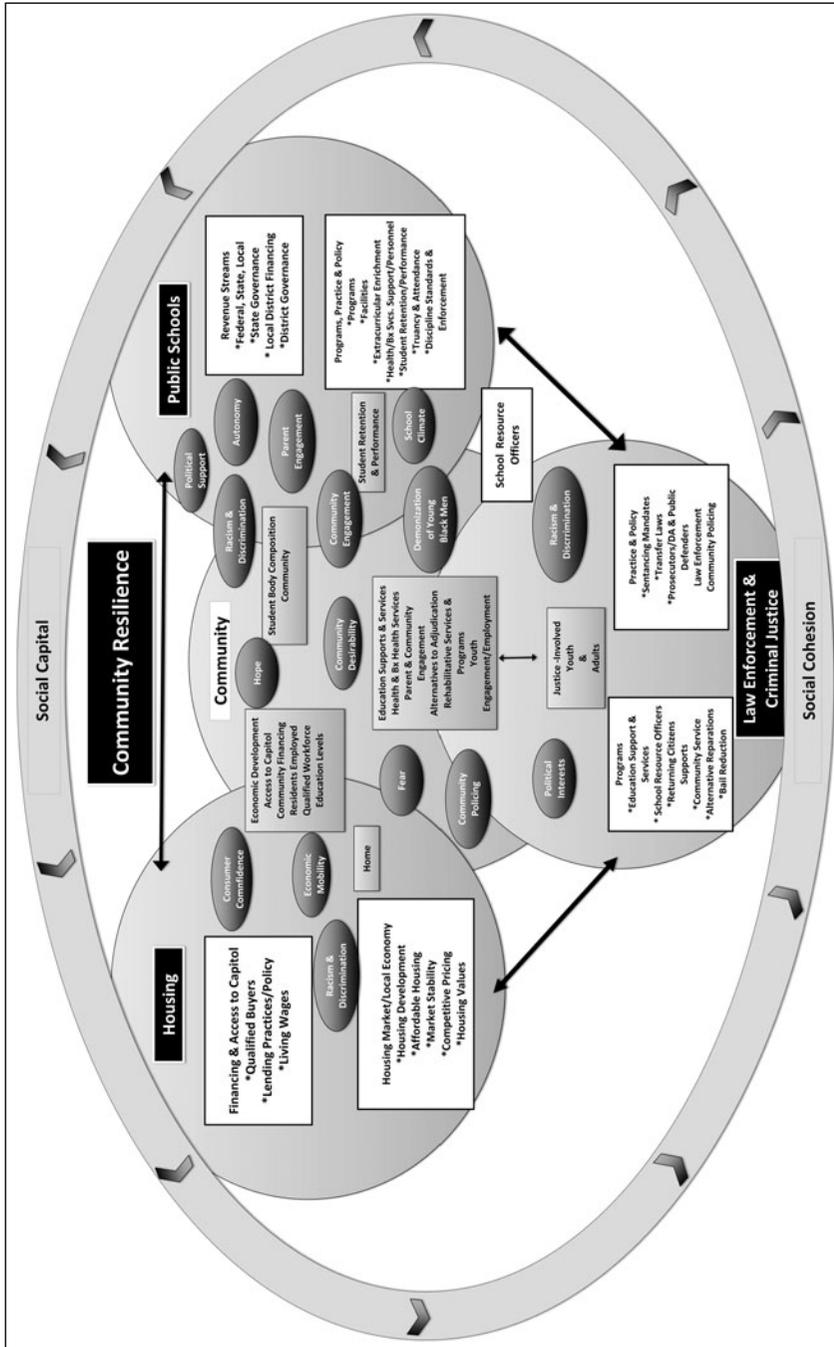
### *System dynamics modeling for public health*

To design this model, we developed pathways between systems that influence CR. These systems are called **domains** in systems modeling. The domains of housing, law enforcement and criminal justice, public schools, and community are shown in Figure 2 as the boxes with dark backgrounds. Each domain has a defined set of relationships and measures that are unique to processes and policies that guide how information, assets, resources, and people move (**flow**) within, enter, or exit the domain. How a flow enters or exits a domain depends upon interactions with other domains and provides public health analysts an opportunity to consider a host of factors that influence accumulation of a **stock**. Stocks in Figure 2 are shown in the boxes with clear backgrounds and can be enabling factors or barriers that influence community and population outcomes associated with the model. The community outcomes (boxes with gray backgrounds) produced by domains of the CR can be qualitative or quantitative and typically represent values, resources, and outputs of the system, such as economic development, student performance, and incarceration rates.

Illustrating several domains allowed us to break large public systems into well-defined pieces that can be tested independently and in combination with each other. We acknowledge that an infinite number of stocks and flows can influence outcomes, but for our initial inquiry we focused on those influenced by long-standing institutional policies, programs, and practices and are firmly established in the social determinant literature.

## Results

We began our analysis of the relationship between housing, public schools, law enforcement, and



**FIGURE 2** The Community Resilience Model: Pathways and Interconnected Domains<sup>a</sup>

Abbreviations: Bx, behavioral; DA, district attorney.

<sup>a</sup>The domains (systems) of housing, public schools, law enforcement, and community resilience are shown in the boxes with clear backgrounds. Community outcomes that are driven by stocks and flows within domains are depicted in gray boxes. Contextual factors that vary by community are placed where they are theorized to have significant influence on the flow between stocks within and across domains.

criminal justice by focusing on community outcomes and factors directly influenced by the behaviors of each system and how the policies and practices of each system interact. These factors are concordant with a body of public health literature that connects employment, housing stability, education, and criminality (social determinants) to health and well-being.<sup>20,21</sup> A system dynamics approach enables an understanding of the complexity of these community interrelationships, including economic development, racial and economic makeup of families, and the level of available social supports and resources. Combined, these factors are also associated with the level of community engagement with systems and local government—a direct indicator of social capital and an influencer of social cohesion.<sup>22,23</sup> Because social capital and social cohesion foster CR, we depict them as elements surrounding the community systems.

As the science of social determinants indicates, the circumstances in which people are born, grow, live, work, and age and the systems influence community outcomes and are shaped by a wider set of forces, including economic and social policies, and politics.<sup>24</sup> As Figure 2 illustrates, the CR model shows how economic and social policies and practices of one domain heavily influence the amount of economic capital and resources supplied by another domain, which, in turn, are directly associated with the amount of additional capital and programs provided to and by other domains. Reinforcing processes compound change in one direction, with even more change in that same direction. As such, they generate either virtuous (growth) or vicious (collapse) cycles.

Housing policies are stocks in the housing domain that influence factors within that domain and community outcomes including access to capital and tax revenue to support local schools. For example, New Deal housing policy (a stock) supported racial segregation and discriminatory lending practices by restricting federally guaranteed mortgages to neighborhoods that were zoned for “Whites only.”<sup>12,25</sup> The outcomes of racial and economic segregation seen in many communities today can trace their origins back to these early 20th-century practices of structural racism.

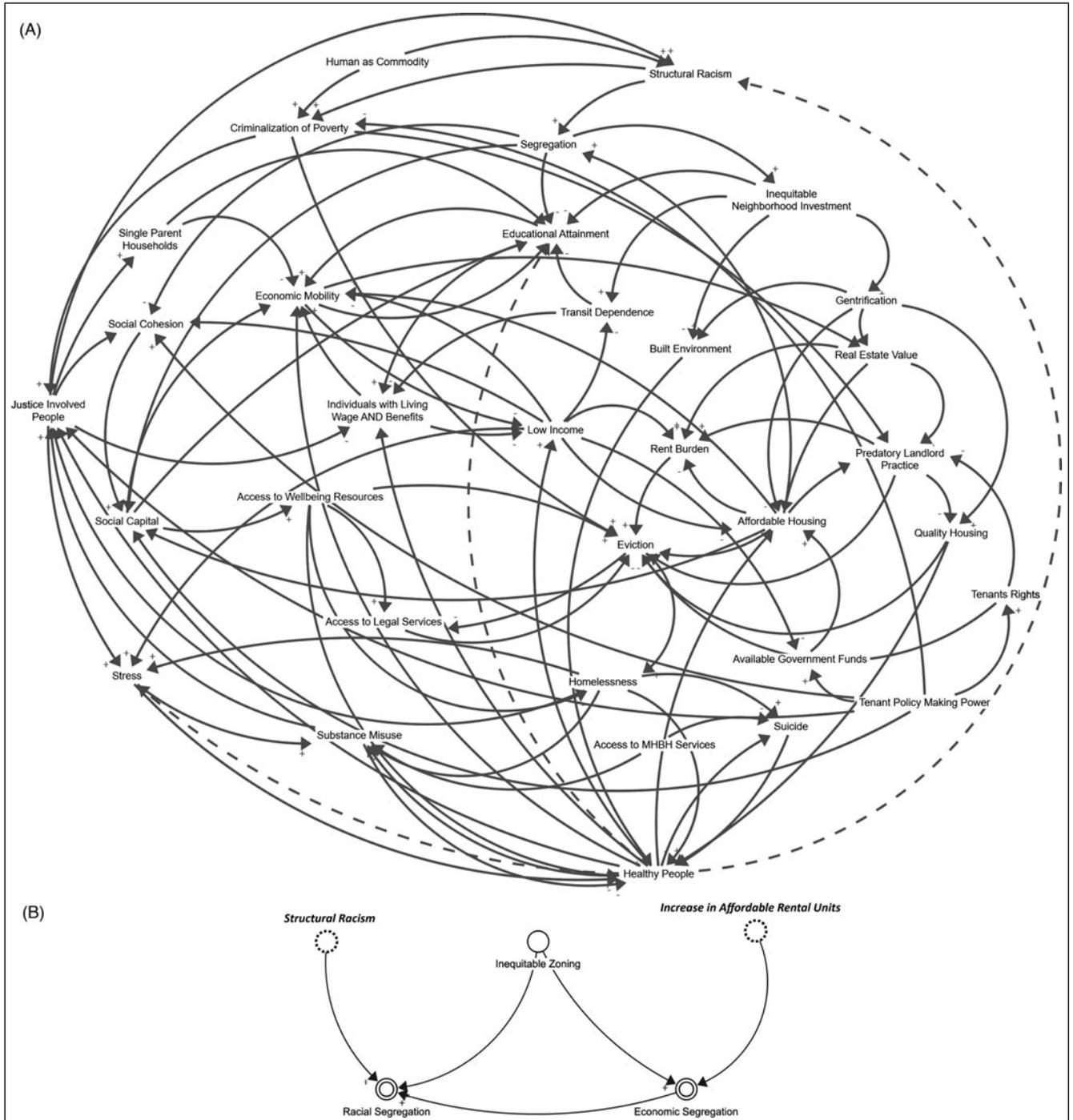
Outcomes of one system can act as mediators or stocks in another system. For example, high school graduation rates are an outcome of the public school system but accumulate as a stock for a community. Likewise, the effect of graduation rates on employment can mediate within a housing system by contributing to increased home ownership rates. The effect is 2-fold: some residents may be more likely to choose to stay in the community after graduating from secondary or higher education because of

increased opportunities afforded to them by their education while increased graduation rates at local schools may also attract more stably employed individuals to a neighborhood to buy homes and raise families. The ability to examine the interconnectiveness of stocks, outcomes, and mediators within and between systems to predict outcomes is a key strength of using system dynamics modeling in public health.

In Figure 2, the domains of schools, housing, and law enforcement and criminal justice each contain stocks that are driven by policy, practice, and programs. The accumulation of stocks within and between each domain is influenced by contextual factors, shown as oval figures with gray backgrounds. Contextuals, such as racism, trust, fear, hope, and cultural values, influence how systems operate and interact with each other as well as how individuals interact with and perceive systems.<sup>26</sup> Understanding how contextual variables influence community and population outcomes and their association with health and well-being provides important insights and levers for public health strategists.

In the CR model, stocks can be measured quantitatively and/or described qualitatively as elements that provide some benefit to the community, such as education supports, health services, and community supports and resources. Outcomes are products of pathways within each domain and can be quantified by measures such as units of affordable housing, eviction rates, amount of community financing available, educational attainment levels, and the number of justice-involved youth. In practice, the development of quantitative measures for stocks, flows, and the context is informed by community stakeholders through qualitative research, and the measures can be community specific.

In the housing domain, we outline stocks in the 2 main categories of “Financing and Access to Capital” and “Housing Market/Local Economy.” In the public schools domain, we list stocks in the 2 main categories of “Revenue Streams” and “Programs, Practice and Policy.” In the law enforcement and criminal justice domain, we outline stocks in the 2 main categories of “Programs” and “Practice and Policy.” The stocks within domains influence stocks across domains in balancing or reinforcing manners along flows that are depicted by arrows. For example, Figure 3A shows a Causal-Loop Diagram (CLD) built for Louisville, Kentucky, based on information provided to us by the local health department and its community partners to understand how structural racism results in disproportional evictions. The CLD depicts the relationships among variables from housing, criminal justice, and education systems as well as social needs and health

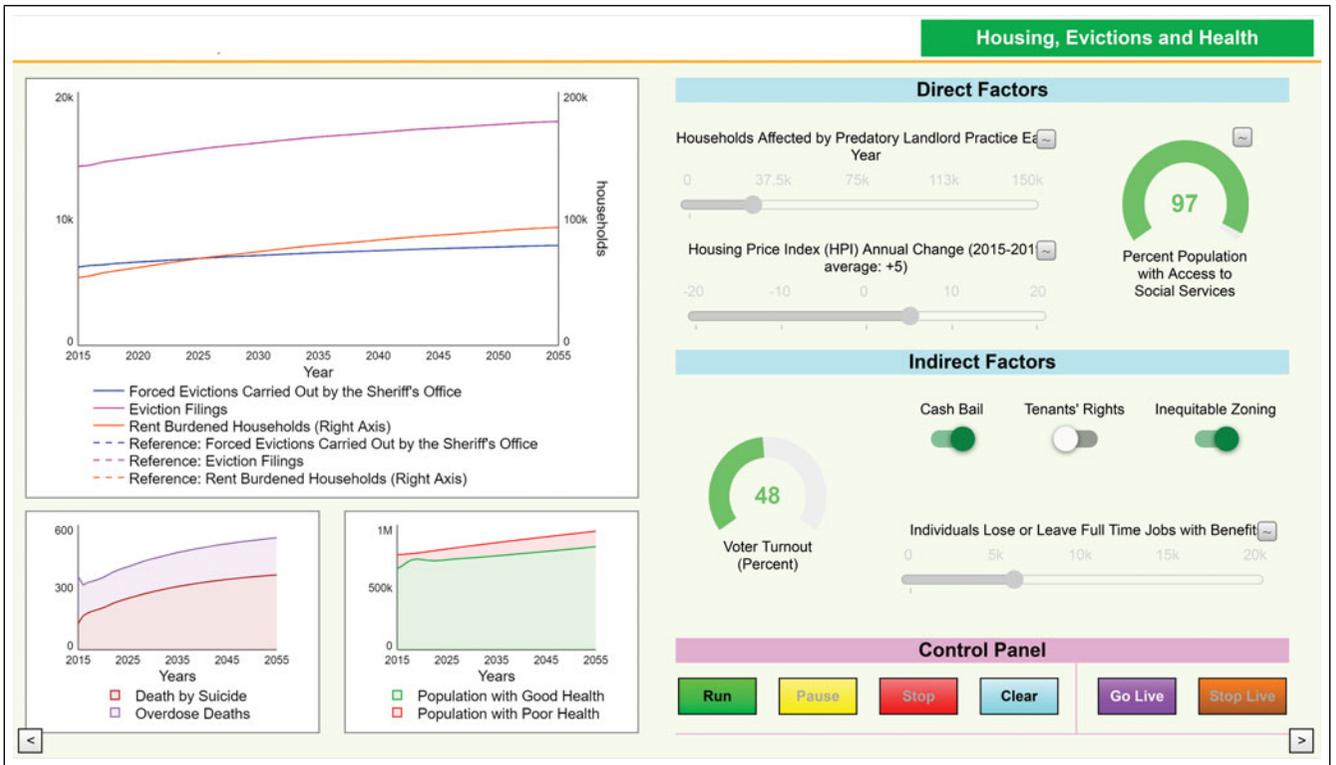


**FIGURE 3** (A) Causal-Loop Diagram of the Louisville, Kentucky System Dynamics Model Depicting Causal Relationships Among Variables Related to Housing, Criminal Justice, and Education Systems<sup>a</sup>

Abbreviation: MHBH, Mental Health Behavioral Health.

<sup>a</sup>The CLD was created on the basis of qualitative data provided by cross-sector partners and the Louisville Metro Department of Public Health and Wellness serving as the chief health strategist. Dashed arrows denote noncausal relationships where information from one variable is imported into another for formulating equations.

(B) A Further Detailed Model of Converter Variables Depicting Structural Racism, Inequitable Zoning Policy and Regulation, and Economic Segregation Together Contribute to Reinforcement of Racial Segregation, as Indicated by the Plus Signs on the Arrows



**FIGURE 4** Simulation Interface for the Louisville System Dynamics Model<sup>a</sup>

<sup>a</sup>The simulation interface is a predictive analytics tool that helps cross-sector partners identify and build consensus on their priorities for policy action. Definitions of indicators and levers, information on how to read the data outputs, and instructions for how to use the interface levers and control buttons are included in additional pages (not shown) of the interface. This figure is available in color online ([www.JPHMP.com](http://www.JPHMP.com)).

variables. In Figure 3B, we provide a zoomed-in Stock-and-Flow modeling view of converter variables illustrating the causal relationships around segregation: structural racism, inequitable zoning laws and regulations, and economic segregation, all of which reinforce racial segregation in Louisville. As seen in Figure 4, we then used the model to simulate how policy solutions could address the effects of structural racism. Indicators and levers shown in Figure 4 were identified by community stakeholders through key informant interviews and feedback from the local health department teams as well as through a community feedback session. The interface in Figure 4 is customizable and can be further modified on the basis of additional community feedback.

As the Louisville model demonstrates, domain flows influence stocks of the community. Community stocks are outcomes that are heavily influenced by the interaction of these domains, such as economic development, educational attainment, community engagement, and the number of justice-involved youth. In addition to the domain-driven outcomes (stocks) in the community, our model of CR considers contextu- als that influence how domains operate and the outcomes (stocks) they produce.

### Community outcomes

Characteristics of communities reflect the consequences of the stocks and flows within major public domains. These characteristics include home ownership (outcomes of the housing system), student retention and performance (outcomes of the public school system), and the number of justice-involved youth and adults (consequences of the law enforcement and criminal justice system) as illustrated in the gray boxes in Figure 2. The availability of community-based services is largely governed by stocks and flows within systems and directly influences several community outcomes. These systems-driven community outcomes can serve as key community indices to measure the direction and intensity of the system's overall reinforcing pattern. In other words, community outcomes, such as high school graduation rates, incarceration rates, and homelessness, are systems performance indicators. As discussed earlier, reinforcing patterns are the engine of growth or collapse because they compound change in one direction, with even more change in that direction. For example, interactions between the housing, public schools, and law enforcement and criminal justice domains can

produce a vicious cycle such as the “school-to-prison pipeline.” A virtuous cycle may result from increased graduation rates (outcome of public schools domain) for a community that results from multiple flows, including stabilized housing for families (outcome of the housing domain), increased investment in school personnel and curriculum (stocks of the public schools domain), more alternatives to incarceration (stock of the law enforcement and criminal justice domains), and decreased arrests of delinquent youth (outcome of the law enforcement and criminal justice domains).

Where systems converge and share characteristics in practice and policy are especially important aspects of systems analysis because they illustrate the interconnected influences on CR. As the arrow in Figure 2 between the stocks of School Program, Practice and Policy, and Law Enforcement Practice and Policy shows, the presence of resource and law enforcement officers in schools is a shared characteristic of community, law enforcement and criminal justice, and public schools. This relationship illustrates the interconnectivity between systems and community and further demonstrates how multiple flows within and across domains produce reinforcing patterns between schools and the law enforcement and criminal justice system, resulting in the school-to-prison pipeline.

We chose to follow established frameworks for CR in which health status and behaviors are outcomes or by-products of multiple systems and their interaction with contextual factors, as opposed to products of health care or public health. This approach requires public health leaders to rethink how we communicate our goals—using language that is more inclusive of outcomes and impact from multiple sectors.

## Discussion

The CR model is designed to assist local public health and partners from multiple sectors to systematically identify, measure, and address inequities produced by structural racism contribute to adverse childhood experiences and adverse community environments (the pair of ACEs). A key role of the CHS is working across sectors to drive initiatives that address the upstream social determinants of health.

Applying system dynamics modeling to public health management allows public health practitioners to apply systems thinking prospectively to public health planning. The model presented here accounts for the complexity and effects of multiple public systems and associated factors over time. The models produced using this method incorporate the dynamics of reinforcing and balancing loops into cause-effect relationships that represent how social systems behave and their associated outcomes. System dynamics

modeling allows integration of multiple stocks into a logical, sequenced, and measurable set of actions and strategies that can be used to track progress toward equity over time.

CR demonstrates that the domains of housing, public schools, and law enforcement and criminal justice all play a role in driving outcomes at the community level. These outcomes include the concentration of poverty (housing driven), educational attainment (public schools driven), and the number of justice-involved residents (law enforcement and criminal justice driven). Many of the outcomes build upon each other in vicious cycles, driven by policy and practice across all 3 domains. All of the systems-driven outcomes, as well as many other variables outlined in the domains, are well-recognized social determinants of health. While social determinants are thoroughly discussed in the literature, no previous models have brought together these outcomes using a system dynamics modeling approach to demonstrate inequities driven by structural racism. Resilience and equity are multifaceted concepts that require measurement of several factors that occur upstream from outcomes.

As part of a growing CDC-funded Resilience Catalysts in Public Health (RC) network, the CR model is being implemented in 9 local health jurisdictions across the country including Alameda County Public Health (California); Baltimore City Health Department (Maryland); Florida Department of Health-Leon County; Shelby County Health (Tennessee), Tacoma-Pierce County Health (Washington); AppHealthCare (North Carolina); Cambridge Public Health (Massachusetts); Louisville Metro Department of Public Health and Wellness (LMD-PHW) (Kentucky); and Mesa County Public Health (Colorado).

Local health departments in the RC network use the CR model to examine and confront drivers of inequity identified at the community level. In 2020, the Tacoma-Pierce County Board of Health unanimously passed a resolution declaring racism a public health crisis.<sup>27</sup> The Department organized an internal Racism and Resilience Action Team (RRART) that is now implementing the CR model to support their efforts to tackle racism and inequity. The team’s work is data driven and aims to use the CR model to identify gaps and create new policies to promote racial equity and justice. They are convening community-based organizations, cross-sector agencies, and key stakeholders to develop a system dynamics model that helps illustrate drivers of systemic inequity across housing, education, and criminal justice that may contribute to community factors that create cycles of inequity and adversity contributing to infant mortality and suicidality in youth and adults within the Black,

## Implications for Policy & Practice

- The CR model is being used by local public health departments to develop equity measures and monitor change over time in systems-driven community outcomes that drive disparity. Five additional Resilience Catalysts sites will be added in late 2021.
- Leveraging the power of data across systems coupled with population health data, CHS and other public health practitioners can lead efforts to change community environments through program, policy, and practice to improve health and well-being—building resilience through equity.

Indigenous, and Pacific Islander communities. This model will result in a community-level dashboard of equity indicators that will be released in spring 2022.

The Center for Health Equity and LMDPHW (Kentucky) is implementing the CR model to reduce evictions in communities of color by developing and advocating for supportive policies for renters and grounding their work in data and analysis of the local context. Louisville-Jefferson County, like many other communities across the country, is highly segregated by race and income—a measurable legacy of racist practices such as redlining and discriminatory lending practices.<sup>28</sup> Eviction filing rates are higher in parts of the county that have higher concentrations of poverty and Black residents. The LMDPHW is using the CR model to research and promote equitable housing policy and practice by developing community-driven policy solutions. Leaders at the LMDPHW plan to use the interactive system dynamics model developed through RC participation to identify supportive policies for renters at the state and local levels that can improve health outcomes and promote health equity in Louisville.

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