MINDING THE GAP: AN INTRODUCTION TO EMPIRICAL CRITICAL RACE SCHOLARSHIP AND COMPLEXITY SCIENCE (WITH RESOURCES ON AGENT-BASED MODELING)*

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This essay explores the potential for complexity science to bridge the epistemic gap between critical race theory ("CRT") and empiricism. It begins by outlining the conflicting epistemologies of CRT, which values subjective knowledge rooted in narrative descriptions of lived experiences, and empiricism, which values objective analysis. This divergence poses challenges for empirical CRT scholars seeking to integrate critical perspectives with rigorous statistical methods. The essay then introduces complexity science, which studies emergent phenomena in complex adaptive systems. Complex systems are characterized by being composed of a large number of agents whose collective action emerges from simple rules determining individual behavior. This emergent behavior is impossible to precisely predict, in part because very slight changes in conditions can lead to large-scale changes in the resulting emergent behavior. Complex systems have been found to exist in many natural phenomena, from subatomic events to biological and social systems, to large-scale planetary interactions. Complexity science has a growing influence in social science, where it is providing new insights into what social systems are and how they work together in assemblages. Concepts like nonlinear scaling and assemblages are shown to be relevant for understanding the dynamics of social ontologies relevant to understanding race. Complexity science can benefit CRT by providing a nuanced social theory attentive to the contextual factors revealed by complex systems theory. To demonstrate these advantages, this essay considers examples like Schelling's

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segregation model, agent-based modeling of health inequities, and modeling incarceration as an infectious disease. In doing this, it demonstrates complexity science's potential to illuminate the multifaceted, nonlinear nature of race. Moreover, the philosophy of information and Bayesian epistemology offers additional resources for bridging the epistemic divide. This essay concludes by outlining implications for empirical critical race theory, including embracing assemblage frameworks, nonlinear causality, and structural realism. It cautions that complexity science alone cannot offer a complete theory, highlighting the need to supplement quantitative analysis with human narratives. It makes a case for complexity science expanding CRT's methodological toolkit while retaining its core critical commitments. The synthesis of critical perspectives with complexity science and information theory holds promise for elucidating the workings of structural racism.

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INTRODUCTION

Nature loves to hide
(Phusis kruptesthai philei)[1]
–Heraclitus

Heraclitus's aphorism provoked two attitudes among the ancient Greeks. In one version associated with the Prometheus myth, nature jealously hides from prying eyes, and those who violate her will be punished.[2] The other reading, which references the myth of Orpheus, views Nature as coyly concealing her bounty, tempting the curious to investigate her delights.[3] Contemporary social thought, which explores the nature of society and social behavior through vast quantities of data and powerful computers, might read Heraclitus to mean "knowledge about social behavior can be dangerous to discern." Is the new empirical social thought Prometheus serving new colonialist masters who will

1. In *The Veil of Isis*, Perrie Hadot's study of the myth of Isis, Hadot analyzes this aphorism attributed to Heraclitus. He concludes, however, that it did not originate from Heraclitus himself. PIERRE HADOT, THE VEIL OF ISIS 9 (Michael Chase trans., 2006) ("[O]ur aphorism would then mean, 'that which results from the process of birth tends to disappear.'"). Delving deeper into the linguistic nuances, Hadot contends that the term "*philein*" may not connote "to love" in this context, but rather, "to be accustomed to" or "to habitually do" a verb, particularly in relation to the verb "*kruptesthai*," which can signify "to hide" or "to bury." *Id.* at 8–9. Moreover, Hadot challenges the conventional translation of the subject of the verb, "*phusis*," as "nature." *Id.* at 8. According to Hadot's substantial scholarly investigations, during Heraclitus's era, "*phusis*" encompassed diverse interpretations such as the intrinsic nature of individual entities (in contrast to nature as a unified whole), or the process of actualization, genesis, manifestation, or growth of a thing. *Id.* at 8. These multifaceted possibilities hinge upon the precise understanding of "*kruptesthai*." *Id.* Although it may denote concealment, Hadot astutely highlights its alternative connotation of burial. *Id.* at 9. Hence, Hadot concludes, the translated phrase can be construed in one of two ways: either (a) as "[w]hat causes birth [*phusis*] also tends [*philei*] to cause disappearance [*kruptesthai*]," or (b) as "[t]hat which results from the process of birth [*phusis*] tends [*philei]* to disappear [*kruptesthai*]," succinctly conveying the notion that the form that emerges eventually fades away. *Id.* at 9. In Hadot's estimation, both of these alternatives suggest the "antithetical character" intrinsic to Heraclitus' philosophical outlook, effectively conveying the profound wonder he experienced when confronted with the processes of metamorphosis and the intrinsic interconnectedness of life and death. *Id.* at 10. Demonstrating the breadth of his erudition, Hadot further traces the trajectory of this thought, deftly connecting it to the philosophy of Marcus Aurelius, Montaigne, Rilke, Princess Bibesco, Claude Bernard, François Jacob, Jean-Claude Ameisen, and Félix Ravaisson—individuals who, while perhaps unfamiliar to Anglophone readers, encompass doctors, biologists, and artists alike. *Id.* at 7–10.

2. *Id.* at 95.

3. *Id.* at 96.

oppress and enslave? Or will it be like Nature in the Orpheus myth, opening hearts and inviting harmony and prosperity?

The fundamental tension between these two metaphors lies at the foundation of the movement known as empirical critical race theory ("eCRT"), which seeks to use the lessons learned from the empirical social sciences in the larger project of critical race theory. The project of eCRT is born in the hope that empirical science will enhance CRT, transforming race scholarship by unifying the rich cultural insights of CRT and the rigorous objectivity of empirical research. The work of eCRT scholars resounds with promise and urgency, heralding a new era where empirical rigor promises to reshape the contours of social consciousness. As a testament to this movement's promise, many essays, symposia, and workshops have been written and organized to foster and facilitate this interdisciplinary work.[4] Empirical CRT rests at the crux between two epistemological theories: critical theory and empirical social science, which are divided by conflicting (even mutually exclusive) theories of knowledge (epistemologies) that form a divide that cannot be crossed.[5] Numerous scholars have laid bare the intricate nuances of this epistemic tension.[6] According to the standard

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4. *See, e.g.*, Khiara Bridges, *The Dangerous Law of Biological Race*, 82 FORDHAM L. REV. 21 (2013); Roy L. Brooks, Conley *and* Twombly*: A Critical Race Theory Perspective,* 52 HOW. L.J. 31 (2008); Devon W. Carbado & Mitu Gulati, *Working Identity,* 85 CORNELL L. REV. 1259 (2000); Devon W. Carbado & Mitu Gulati, *The Law and Economics of Critical Race Theory*, 112 YALE L. J. 1157 (2003); Jerry Kang, *Bits of Bias*, *in* IMPLICIT RACIAL BIAS ACROSS THE LAW 132 (Justin Levinson & Robert Smith eds., 2012); Osagi K. Obasogie, *Race in Law and Society: A Critique*, *in* RACE LAW AND SOCIETY 445 (Ian Haney-Lopez ed., 2006); Osagi K. Obasogie, *Beyond Best Practices: Strict Scrutiny as a Regulatory Model for Race-Specific Remedies*, 36 J.L. MED. & ETHICS 491 (2008); Osagi K. Obasogie, *Race, Genetics, and the Regulatory Need for Race Impact Assessments*, *in* RACE AND THE GENETIC REVOLUTION: SCIENCE, MYTH, AND CULTURE 255 (Sheldon Krimsky & Kathleen Sloan eds., 2011); Osagi K. Obasogie, *Foreword: Critical Race Theory and Empirical Methods*, 3 U.C. IRVINE L. REV. 183 (2013) [hereinafter Obasogie, *Foreword*]; Daria Roithmayr, REPRODUCING RACISM: HOW EVERYDAY CHOICES LOCK IN WHITE ADVANTAGE (2014).

5. *See, e.g.*, Dorothy A. Brown, *Fighting Racism in the Twenty-First Century*, 61 WASH. & LEE L. REV. 1485 (2004); Jerome M. Culp, Angela P. Harris, & Francisco Valdes, *Subject Unrest*, 55 STAN. L. REV. 2435 (2003).

6. Carbado writes,

> The relative newness of this group and the absence of more scholarship at the intersection of CRT and the social sciences may reflect what some have called an "unacknowledged schism" between the two fields. Indeed, some critical race theorists have expressly argued that social

account, at the heart of critical race scholarship lies the radical claim that all knowledge is not objectively true but is culturally constructed and reflects the dominant group's power.[7] More precisely, since claims of truth are cultural constructions, they are inexorably intertwined with social structures that foster and sustain power relationships.[8] That means

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> science is potentially antithetical to the core critical commitments that characterize CRT.

Devon W. Carbado, *Critical Race Theory Meets Social Science*, 10 ANN. REV. L. & SOC. SCI. 149, 150 (2014) [hereinafter Carbado, *Critical Race Theory Meets Social Science*] (first citing Obasogie, *Foreword*, *supra* note 4; and then citing Brown, *supra* note 5; and then citing Culp, Harris, & Valdes, *supra* note 5).

7. For example, Obasogie explains,

> The work leading up to this symposium issue starts from the observation that there seems to be an unacknowledged schism between critical race scholarship and the social sciences. To be sure, individual scholars have examined particular areas of race scholarship—most notably, the social psychology of implicit bias—through a lens that uses social science methods to measure these dynamics and critical race perspectives to frame their legal significance. However, there has not been a sustained conversation beyond this literature concerning the importance of building bridges between these two communities to tease out the opportunities and challenges associated with extending a joint critical race and empirical effort to other areas of race scholarship, whether it be health disparities, gaps in educational achievement, or issues pertaining to criminal justice.

Obasogie, *Foreword, supra* note 4, at 184 (citation omitted).

8. Brown summarizes CRT scholarship's approach by writing, "[a]lthough CRT does employ a single methodology, it seeks to highlight the ways in which the law is not neutral and objective, but designed to support White supremacy and subordination of people of color." Brown, *supra* note 5, at 1486 (citations omitted). Similarly, Carbado writes,

> Perceiving the researcher to be detached and neutral is potentially at odds with a crucial starting point of CRT: the idea that knowledge production is contingent on the combined effects of the researcher, the social and political context in which she is situated, and the inquires and frameworks she employs.

Carbado, *Critical Race Theory Meets Social Science*, *supra* note 6, at 159. Culp, Harris, and Valdes write from an explicitly poststructuralist perspective and claim that the subject is never independent:

> Critical race theory, at its best, attempts to resist the right's and left's demands that the subject transcend the conditions of its making while simultaneously resisting the desire, present within some versions of identity politics, to slip off the yoke of subjection and stand revealed as

that claims about what constitutes knowledge are inseparable from social and political power production and maintenance.[9] Therefore,

> an authentic and pure self. This is subject unrest at the most basic level: the struggle against what William Connolly calls "the drive to evil installed in the imagination of wholeness," whether that wholeness represents authenticity or transcendence. Critical race theory's understanding of the subject resists the ideal of wholeness; it also refuses to disclaim engagement with the state and other institutional sites of power, problematic though that power may be.

Culp, Harris, & Valdes, *supra* note 5, at 2438.

9. This claim about power was critical to the work of Michel Foucault, whose work has influenced some CRT scholars. He writes, "[p]ower is everywhere" and "comes from everywhere." MICHEL FOUCAULT, THE WILL TO KNOWLEDGE 93 (1998) [hereinafter FOUCAULT, THE WILL TO KNOWLEDGE] (formerly published under the title "THE HISTORY OF SEXUALITY: VOLUME 1"). Neither intentional agency nor social structure alone determine it. *See id.* This essay reads Foucault as arguing that every society upholds its own governing truth, its distinctive political processes of justifying truth: namely, the particular discourses a claim embraces and empowers as representations of truth. There is some tension in this interpretation, as Foucault's thought evolved over time. The concept of power/knowledge was central to his thought during the 1970s, but it appears to have shifted in the 1980s. For a discussion of the evolution of Foucault's thought, see David Couzens Hoy, *Introduction*, *in* FOUCAULT: A CRITICAL READER 2 (David Couzens Hoy ed., 1986). However, the issue here is not to find the essence of Foucault's thought but to interpret it as it influenced critical race theory. Within this framework, there exist mechanisms and institutions that facilitate the differentiation between true and false assertions, sanctioned through established means. *See* FOUCAULT, THE WILL TO KNOWLEDGE, *supra*. Furthermore, certain techniques and methodologies are accorded significance in the pursuit of truth, shaping its acquisition. *See id.* at 100–02. Equally important is the status bestowed upon those individuals entrusted with the authority to determine what qualifies as truth. *Id.* at 102. The result is the emergence of overarching "universal politics" and "truth regimes" that can be traced back to scientific discourse and institutions, which continually reinforce and redefine them. Foucault took up the theme of "regime of truth" and systems of production of truth throughout his work. For example, in a 1977 essay, he explains,

> Each society has its regime of truth, its "general politics" of truth: that is, the types of discourse which it accepts and makes function as true; the mechanisms and instances which enable one to distinguish true and false statements, the means by which each is sanctioned; the techniques and procedures accorded value in the acquisition of truth; the status of those who are charged with saying what counts as true.

Michel Foucault, *Truth and Power*, *in* THE FOUCAULT READER: AN INTRODUCTION TO FOUCAULT'S THOUGHT 51, 73 (Paul Rabinow ed., 1991).

This process unfolds through the pervasive influence of the education system, the media, and the ever-shifting currents of political and economic ideologies. *Id.* Thus, the ongoing struggle for truth does not revolve around a fixed and absolute truth awaiting discovery and acceptance. *Id.* at 73–74. Instead, it centers on the contestation of "the rules" that govern the demarcation between true and false, and the specific power dynamics that become intertwined with these conceptions of truth. It is fundamentally a battle over the

CRT scholarship, which seeks to overturn the established racist order, seeks a personalist understanding of knowledge rooted in oppressed people's lived human experiences. CRT scholars give epistemic value to narratives that describe the experiences of oppression through societal biases, systemic racism, and oppressive historical contexts.[10] CRT is critical of the dominant narratives of race, which are those of the oppressors, and intends to bring forward the marginalized narratives so that justice might be achieved. CRT scholars resolutely assert that a meticulous and critical interrogation of prevailing narratives and anti-narratives is imperative to unveil knowledge's entanglement with group power dynamics.[11]

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societal standing of truth itself and the intricate economic and political roles it assumes. Foucault explains,

> The essential political problem for the intellectual is not to criticize the ideological contents supposedly linked to science, or to ensure that his own scientific practice is accompanied by a correct ideology, but that of ascertaining the possibility of constituting a new politics of truth. The problem is not changing people's consciousnesses—or what's in their heads—but the political, economic, institutional regime of the production of truth.

Id. at 74.

10. As Carbado explains,

> CRT critiques of neutrality find a foundation in early critical theory, specifically the Frankfurt School. Critics like Horkheimer, Adorno, and Habermas argued against the supposed objectivity of social science as part of a broader set of claims about the relationship between science and objectivity. In particular, these theorists pointed out that scientific understanding of social facts depends on some preexisting categories, classifications, and conventions about what counts as a true or useful scientific fact. These theorists argued that categories, classifications, and conventions are politically and socially constructed and are not themselves factual or observable in any independent way. These early thinkers also observed that the political and social construction of so-called objective facts is often hidden from view, as scientists claim to be simply representing the world as it is.

Carbado, *Critical Race Theory Meets Social Science*, *supra* note 6, at 155 (citation omitted).

11. According to Crenshaw, CRT originated as a "frame *mis*alignment." Crenshaw argues:

> One might say that what nourished CRT and facilitated its growth from a collection of institutional and discursive interventions into a sustained intellectual project was a certain dialectical *mis*alignment. Within the

On the other hand, empirical social scientists value objectivity and logical inference over subjective reports.[12] They want to construct analyses of social systems based on empirical evidence of observed behavior and draw rational inferences from this evidence to formulate rules that explain behavior.[13] Therefore, they assume that an independent, objective observer is possible.[14] They place a premium on detached, objective methodologies. Mindful of the limitations inherent in subjective bias, the social sciences also strive to transcend individual perspectives by relying on empirical data.[15] They often assume that the

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> context of particular institutional and discursive struggles over the scope of race and racism in the 1980s, significant divergences between allies concerning their descriptive, normative, and political accounts of racial power began to crystallize. This misalignment became evident in a series of encounters—institutional and political—that brought into play a set of "misunderstandings" between a range of individual actors and groups.

Kimberlé Williams Crenshaw, *Twenty Years of Critical Race Theory: Looking Back To Move Forward*, 43 CONN. L. REV. 1253, 125–62 (2011) [hereinafter Crenshaw, *Twenty Years*].

Carbado observes that one of the cohorts involved was the forward-thinking Caucasian legal scholars belonging to the Critical Legal Studies (CLS) movement. Devon Carbado, *Critical What What?* 43 CONN. L. REV. 1595, 1597–99 (2011) [hereinafter Carbado, *Critical What What?*]. He argues that Crenshaw can be read to posit that CLS facilitated the emergence of CRT by not only reiterating key concepts regarding the ambiguity of law and its constructive potential (drawing inspiration from Foucault) to shape social structures, hierarchies, and interests, but also by neglecting to genuinely address the role of race as a fundamental phenomenon rather than a mere byproduct within this framework. *Id.* at 1596. When Crenshaw refers to a "misalignment" concerning CLS, she specifically alludes to this shortcoming—the marginalization of race within the movement. *Id.* Although Carbado believes alternative narratives of the origins of CRT are possible, he acknowledges the authority of this narrative. *See id.* at 1596–99 (discussing David M. Trubek's counter-narrative).

12. DANIEL LITTLE, NEW DIRECTIONS IN THE PHILOSOPHY OF SOCIAL SCIENCE 37–72 (2016).

13. "[A] social science [is] any branch of academic study or science that deals with human behaviour in its social and cultural aspects. Usually included within the social sciences are cultural (or social) anthropology, sociology, psychology, political science, and economics." Robert A. Nisbet & Liah Greenfeld*, Social Science*, ENCYC. BRITANNICA, https://www.britannica.com/topic/social-science (Jan. 5, 2024).

14. "Science, any system of knowledge that is concerned with the physical world and its phenomena and that entails unbiased observations and systematic experimentation. In general, a science involves a pursuit of knowledge covering general truths or the operations of fundamental laws." *Science*, ENCYC. BRITANNICA, https://www.britannica.com/science/science (Jan. 28, 2024).

15. "The concept of evidence is the basis of philosophical evidentialism, an epistemological thesis according to which a person is justified in believing a given

motives of individuals are expressed in the collective agency of the group. Emphasizing the collection and analysis of observable phenomena, these disciplines endeavor to uncover generalizable rules that explain causal relationships among individuals. Their ambition is to generate knowledge anchored in evidential support and logical inference into the behavior and motives of individuals.

Resolving the tensions between these two epistemological theories is thus an ambitious, yet vital, project in the data-driven world of the information age.[16] In this period, data is viewed as raw material for commercial exploitation, personal identities are created through data-mining private information, and decisions of profound importance to individual lives are made through autonomous systems.[17] Achieving the theoretical synthesis of CRT and empirical science could hold the key to elevating the discourse on race-related issues to new heights of scholarship and understanding.[18] A cohort of intrepid critical race theorists, operating at the juncture between CRT and the social sciences, has ventured into uncharted territory in the pursuit of this synthesis.[19] Disciplines as diverse as sociology, social psychology, anthropology, economics, psychology, and political science have served as their compass, guiding them toward an exploration of the interconnectedness

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proposition *p* if and only if the person's evidence for *p* is proper or sufficient." Daniel Costa, *Empirical Evidence*, ENCYC. BRITANNICA, https://www.britannica.com/topic/empirical-evidence (Dec. 21, 2023).

16. "Objectivity" encompasses several connotations within the realm of common discourse. By differentiating its adjectival and adverbial forms, the manifold meanings of "objectivity" can be elucidated. Primarily, as an adjective, "objective" can be attributed to phenomena existing in the world. *See Objective*, COLLINS DICTIONARY, https://www.collinsdictionary.com/us/dictionary/english/objective (last visited Jan. 30, 2024) (defining "objective" in its adjectival form). In this sense, it is occasionally inferred that an entity possesses actual existence, as opposed to being a mere semblance or product of the imagination. Alternatively, "objectivity" can connote the affiliation of a thing with the external world, rather than the internal, psychological domain of an individual or group of individuals. *See id.* (defining "objective" in its adverbial form). Thus, in this particular context, while tables and chairs are considered objective, thoughts and feelings are not, despite both potentially being genuine rather than illusory appearances. *See* Julian Reiss & Jan Sprenger, *Scientific Objectivity*, STAN. ENCYC. PHILOSOPHY, https://plato.stanford.edu/archives/win2020/entries/scientific-objectivity (Oct. 30, 2020).

17. For a discussion of the impact of information mining on individual identity, see LUCIANO FLORIDI, THE FOURTH REVOLUTION, 59–86 (2014).

18. *See, e.g.*, Carbado, *Critical Race Theory Meets Social Science*, *supra* note 6, at 149–67.

19. *See, e.g., supra* note 4.

between CRT and the domain of empirical inquiry.[20] A seamless synthesis of CRT and empiricism would not only engender a profound comprehension of the multi-faceted nature of social complexities but also could be a potent force for unmasking and dismantling the covert patterns of systemic racism. In the crucible of this union lies the promise of both social justice and transformative change.[21]

This essay introduces an approach to resolving the tension caused by the epistemic gap. It considers the work of social scientists who have embraced complexity science and suggests that their work holds resources for bridging the epistemic divide between empiricism and critical race theory. Complexity science distinguishes three types of systems based on the amount of order that they have.[22] Random systems have little or no order. For example, molecules in a gas form a random system.[23] The rules for Brownian motion describe the random movement of such systems.[24] Ordered systems have high levels of order. Mechanical systems are highly predictable based on their structure. For example, molecules in a crystal are arranged in lattice structures.[25] Such systems move according to Isaac Newton's classical laws of motion, which is a simple set of rules that can accurately predict the movement of physical objects.[26]

Complex systems fall in between random and highly ordered.[27] They are systems that have more order than random systems and yet are

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20. *See* Nisbet & Greenfeld, *supra* note 13.

21. Obasogie, *Foreword*, *supra* note 4, at 185–86 ("Linking social science methods with critical race theory provides a remarkable opportunity to pursue race scholarship that is both theoretically sophisticated and empirically robust. That is to say, it is an opportunity to think about and measure race in new and exciting ways that builds upon the strengths of multiple disciplines to assess, document, and theoretically extrapolate the hidden ways in which not only law and society construct race, but the way that race constructs law and society.").

22. For a discussion of complex systems from the perspective of measured order, see JAMES LADYMAN & KAROLINE WIESNER, WHAT IS A COMPLEX SYSTEM? 2–15 (2020).

23. *Id.* at 3.

24. *Id.*

25. *Crystal Lattice*, MERRIAM-WEBSTER, https://www.merriam-webster.com/dictionary/crystal%20lattice (last visited Jan. 30, 2024).
"Newton's laws of motion, three statements describing the relations between the forces acting on a body and the motion of the body, first formulated by English physicist and mathematician Isaac Newton, which are the foundation of classical mechanics." *Newton's Laws of Motion*, ENCYC. BRITANNICA, https://www.britannica.com/science/Newtons-laws-of-motion (Jan. 1, 2024).

27. LADYMAN & WIESNER, *supra* note 22, at 122.

less ordered than deterministic systems. Their order is probabilistic, not deterministic, and it is a result of interactions among components.

According to Giorgio Parisi, the physicist who was awarded the Nobel prize for his work in the field,[28] "a system is complex if its behavior crucially depends on the details of the system."[29] Its behavior is intricately influenced by the specific details and characteristics of its constituent elements.[30] An example of a complex system that Parisi poses is a flock (known as a murmuration) of starlings, wherein each bird follows a simple set of rules regarding the distance it should keep from its neighbors and the direction it should fly.[31] Yet, from these simple behaviors, the flock as a whole displays complex formations and aerobatics as the birds interact with feedback loops that exist with each other and their environment.[32] Complexity theorists across many disciplines study such complex systems that are made up of a large number of agents, and as a whole, have collocative behavior that cannot be predicted by simply examining the actions of the individual components.[33] While systems like the flock of starlings are abundant in

28. *See Giorgio Parisi Facts*, NOBEL PRIZE, https://www.nobelprize.org/prizes/physics/2021/parisi/facts/ (last visited Jan. 24, 2024). Giorgio Parisi received the 2021 Nobel Prize in Physics "for the discovery of the interplay of disorder and fluctuations in physical systems from atomic to planetary scales." *Id.* His work revolutionized the understanding of disorder and randomness in physical systems, particularly in the field of statistical physics. *See On the Contributions to Statistical Physics of Giorgio Parisi, Nobel Prize Winner 2021,* ENCYC. ENV'T (Mar. 3, 2021), https://www.encyclopedie-environnement.org/en/physics/parisi-nobel-prize-physics-2021/. He developed innovative mathematical methods and concepts to study the behavior of disordered materials, such as spin glasses, and complex systems, including social networks and optimization problems. *See Thoughts on Complex Systems: An Interview with Giorgio Parisi,* 3 J. PHYSICS 1, 1 (2023). Parisi's research has had a significant impact on various disciplines, from condensed matter physics to computer science and in social science. *See Giorgio Parisi Facts*, *supra*.

29. MELANIE MITCHELL, COMPLEXITY: A GUIDED TOUR 4 (2009); Giorgio Parisi, *Complex Systems: A Physicists Viewpoint*, 263 PHYSICA A 557, 560 (1999) [hereinafter Parisi, *Complex Systems*].

30. *Id.* at 560–61.

31. GIORGIO PARISI, IN A FLIGHT OF STARLINGS: THE WONDERS OF COMPLEX SYSTEM 1–18 (Anna Parisi trans., 2023) [hereinafter PARISI, STARLINGS].

32. *Id.* at 1–2.

33. For a popular introduction to complexity science, see MITCHELL, *supra* note 29; JOHN HOLLAND, SIGNALS AND BOUNDARIES: BUILDING BLOCKS OF COMPLEX ADAPTIVE SYSTEMS (2014); JOHN H. MILLER, A CRUDE LOOK AT THE WHOLE: THE SCIENCE OF COMPLEX SYSTEMS IN BUSINESS, LIFE, AND SOCIETY (2015). For a more sophisticated introduction to complexity science, see YANEER BAR-YAM, DYNAMIC OF COMPLEX SYSTEM (Robert L. Devaney ed., 1992). Also useful for the themes discussed in this essay is LADYMAN & WIESNER, *supra* note 22, which introduces the role of information in complex

nature, their discovery, and the detailed study of them is relatively recent. It was made possible by the groundbreaking advancements in probabilistic prediction made by Maxwell, Boltzmann, and Gibbs during the latter half of the nineteenth century, which revolutionized the field of physics and opened the door to the development of statistical mechanics.[34] This paradigm shift introduced probabilistic reasoning as a powerful tool for understanding the behavior of complex systems.

Due to the inherent complexity and interdependencies within these systems, it is impossible to determine their behavior without understanding the fundamental elements and their interactions. Consequently, researchers turn to probabilistic reasoning to determine the probability distribution of potential behaviors within a set of systems, each characterized by a unique arrangement of elements and interactions.[35] Through this probabilistic approach, scientists like Parisi identify the most minimalistic model capable of reproducing observed features across a diverse range of models.[36] By leveraging the power of probability, researchers can navigate the intricate landscape of complex systems, offering valuable insights into their behavior and uncovering underlying patterns that govern their dynamics.[37] This scientific pursuit allows for a deeper understanding of the fundamental principles that shape our universe.[38]

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systems. For historical background on the development of complexity science, see DAVID C. KRAKAUER, WORLDS HIDDEN IN PLAIN SIGHT: THE EVOLVING IDEA OF COMPLEXITY AT THE SANTA FE INSTITUTE (1984–2019) (2019).

34. *See* Parisi, *Complex Systems*, *supra* note 29, at 557–63.

35. *Id.* at 561–63.

36. Parisi notes, "It was Galileo Galilei who found one of the most powerful tools for investigating nature: simplifying phenomena." PARISI, STARLINGS, *supra* note 31, at 81.

37. Parisi, *Complex Systems*, *supra* note 29, at 558.

38. Complexity science has influenced many areas of science and social science. Bar-Yam notes,

> The study of complex systems in a unified framework has become recognized in recent years as a new scientific discipline, the ultimate of interdisciplinary fields. It is strongly rooted in the advances that have been made in diverse fields ranging from physics to anthropology, from which it draws inspiration and to which it is relevant.

BAR-YAM, *supra* note 33, at 1.

On this understanding of complexity science, noted social theorists like Paul Cilliers[39] and Manuel DeLanda[40] have demonstrated the significance of complexity science for social thought. This essay suggests that by embracing complexity science, eCRT can transcend the epistemic divide and allow scholars to delve more deeply into the labyrinthine interplay between race, power, and social phenomena, and pave the way for transformative social change. A particular tool is agent-based modeling ("ABM"), which draws its foundational assumptions from complexity science. Using ABM could expand the scholarship of complexity science into the CRT corpus. This is warranted and promising.

The claim advanced here is that complexity science appears to hold the potential to bridge the epistemic gap between CRT and empiricism by engaging with the nuances of these divergent approaches and elucidating the contributions of complexity science. This essay introduces an exposition that paves the way for fruitful interdisciplinary dialogue and opens new avenues for the advancement of critical race scholarship. It is divided into four parts. Part I interprets the epistemological dichotomy that exists between critical race theory

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39. DAVID BYRNE AND GILLIAN CALLAGHAN, COMPLEXITY THEORY AND THE SOCIAL SCIENCES: THE STATE OF THE ART (2014) (offering a comprehensive overview of how complexity theory has been integrated into social science research, including sociology, and situating Cilliers's contributions within a broader context of the field's development). *See generally* PAUL CILLIERS, COMPLEXITY AND POSTMODERNISM: UNDERSTANDING COMPLEX SYSTEMS (1998); Paul Cilliers, *Boundaries, Hierarchies and Networks in Complex Systems*, 5 INT'L J. INNOVATION MGMT., 135 (2001) (exploring the concepts of boundaries, hierarchies, and networks within the context of complex systems, offering insights that are directly applicable to the analysis of social structures and dynamics); Rika Preiser & Paul Cilliers, *Unpacking the Ethics of Complexity: Concluding Reflections*, *in* COMPLEXITY AND THE PHILOSOPHY OF BECOMING 265 (C. Allen, G. Richardson, & J. Goldstein eds., 2010) (delving into the ethical considerations arising from the complexity of systems, reflecting Cilliers' interest in how complexity theory informs ethical decision-making, with implications for sociological research and practice); Francis Heylighen, Paul Cilliers, & Carlos Gershenson, *Complexity and Philosophy*, *in* COMPLEXITY, SCIENCE AND SOCIETY 117 (Jan Bogg & Robert Geyer eds., 2010).

40. Bent Meir. Sørensen, *Giles Deleuze and the Intensification of Social Theory*, 3 EPHEMERA 50 (2003) (describing DeLanda as transgressing the dichotomies between analytic and continential philosophy in "truly original reconstructions" of central concepts); Karl Palmås, *Deleuze and DeLanda: A New Ontology, a New Political Economy?* (Economic Sociology Seminar Series, Department of Sociology, LONDON SCH. OF ECONS. & POL. SCI., Jan. 29, 2007) (arguing that DeLanda's thought is useful in economics and sociology). For an introduction to DeLanda's thought, see generally MANUEL DELANDA, A NEW PHILOSOPHY OF SOCIETY: ASSEMBLAGE AND SOCIAL COMPLEXITY (2019).

(CRT) and the empiricist tradition. It argues that the pursuit of objectivity inherent in empiricism is incongruent with CRT's assertions concerning power dynamics and the socially constructed nature of knowledge. The incompatibility between these paradigms demands a nuanced examination to understand the challenges posed by their epistemic divergence. Part II argues for an alternative epistemological perspective that is suggested by developments in complexity science. It begins by describing the fundamental tenets of the Shannon Information Theory and complexity science, and then suggests their relevance to epistemological tensions between empiricism and CRT. Part III outlines Paul Cilliers's and Manuel DeLanda's contributions in applying complexity science to social thought. It illuminates the significance of concepts such as assemblages, multiplicity, and the dynamic interrelationships between system elements, which have proven instrumental in the development and ongoing advancement of complexity science. The influence of these ideas permeates contemporary research endeavors, resonating profoundly with scholars across disciplines. Part IV concludes the essay by suggesting the potential role of complexity science as an enrichment of CRT, which would add to the storytelling methodology often employed within critical race theory. By bringing complexity science into the fabric of CRT, a compelling narrative framework may emerge, capable of capturing the intricate nuances of power dynamics and systemic inequalities. This synthesis offers promising prospects for CRT scholars to augment their theoretical arsenal and wield complexity science as a tool to deepen their understanding of the socio-cultural complexities at play.

I. THE EPISTEMIC GAP: CRITICAL THEORY AND EMPIRICISM

A. The Epistemology of Critical Race Theory: A Philosophical Perspective

CRT emerged in the 1980s—an era that witnessed the emergence of novel perspectives capable of confronting the inadequacies of conventional civil rights theories—as a seminal chapter

in the struggle against systemic racial inequality.[41] Distinguished legal scholars Derrick Bell,[42] Kimberlé Crenshaw,[43] Mari Matsuda,[44] Richard Delgado,[45] and Patricia Williams[46] shattered the orthodoxy of legal thought and ushered in groundbreaking work that became CRT.[47] In the early 1980s, Derrick Bell's magnum opus, *Race, Racism, and American Law*,[48] heralded a paradigm shift, beckoning society to grapple with the inescapable reality that racial justice often materializes only when it intersects with the self-interest of white individuals.[49] Bell introduced the notion of "interest convergence," which laid bare the limitations of attempts to cajole white individuals into championing racial equality without fundamentally challenging the pervasive structures of power

41. Critical race theory developed in the 1980s as an effort by activists and legal scholars to understand why the U.S. civil rights movement had lost momentum and was in danger of being reversed. *See* Jacey Fortin, *Critcal Race Theory: A Brief History*, N.Y. TIMES (NOV. 8, 2021), https://www.nytimes.com/article/what-is-critical-race-theory.html. Their approach emphasized general and systemic features of the legal system that served to perpetuate race-based oppression and white privilege; *see Critical Race Theory*, ENCYC. BRITANNICA, https://www.britannica.com/topic/critical-race-theory (Dec. 24, 2023).

42. *See* Jelani Cobb*, The Man Behind Critical Race Theory*, NEW YORKER (Sept. 13, 2021), https://www.newyorker.com/magazine/2021/09/20/the-man-behind-critical-race-theory. For an introduction to Derrick Bell's life and work, see Fred A. Bernstein, *Derrick Bell, Law Professor and Rights Advocate, Dies at 80*, N.Y. TIMES (Oct. 6, 2011), https://www.nytimes.com/2011/10/06/us/derrick-bell-pioneering-harvard-law-professor-dies-at-80.html, which notes, "Mr. Bell was the first tenured black professor at Harvard Law School and later one of the first black deans of a law school that was not historically black. But he was perhaps better known for resigning from prestigious jobs than for accepting them."

43. *See Kimberlé W. Crenshaw,* AM. ACAD. ARTS & SCIS. (Jan. 2024), https://www.amacad.org/person/kimberle-w-crenshaw; Aamna Mohdin, *Kimberlé Crenshaw: The Woman Who Revolutionised Feminism—And Landed at the Heart of the Culture Wars*, GUARDIAN (Nov. 12, 2020), https://www.theguardian.com/society/2020/nov/12/kimberle-crenshaw-the-woman-who-revolutionised-feminism-and-landed-at-the-heart-of-the-culture-wars.

44. *See* Eunsong Kim & Gelare Khoshgozaran, *Mari Matsuda: Founding Critical Race Theorist, Activist and Artist*, CONTEMP. BLOG (Apr. 30, 2017), https://contemptorary.org/mari-matsuda/.

45. *See Living History Interview with Richard Delgado & Jean Stefancic*, 19 TRANSNAT'L L. & CONTEMP. PROBS. 221, 224–30 (2010).

46. *See Williams, Patricia J. 1951-*, ENCYCLOPEDIA.COM, https://www.encyclopedia.com/arts/educational-magazines/williams-patricia-j-1951 (last visited Jan. 30, 2024).

47. For a history of the founding of CRT, see Crenshaw, *Twenty Years*, *supra* note 11.

48. DERRICK BELL, RACE, RACISM, AND AMERICAN LAW (6th ed. 2008).

49. *See* Leon Higginbotham, Jr., *Book Review: Race, Racism and American Law*, 122 U. PENN. L. REV. 1044 (1974).

that perpetuate racism.[50] A pivotal moment arrived in 1989, when Crenshaw created the neologism "intersectionality" through her seminal essay "Demarginalizing the Intersection of Race and Sex."[51] This groundbreaking contribution illuminated the unique experiences of Black women who confronted the simultaneous forces of racism and sexism.[52] Intersectionality swiftly became a cornerstone of CRT, expanding its purview to encompass the intersecting oppressions faced by other marginalized groups, such as LGBTQ+ individuals and people with disabilities.[53] These intellectual milestones etched by Bell, Crenshaw, and their compatriots laid the foundation for a robust and nuanced analysis of the complex entanglements of race, power, and identity. The far-reaching influence of CRT is felt not only within the academy, but also in the broader struggle for social justice, as it emboldens voices long relegated to the margins and brings forth a more comprehensive understanding of the intersecting forces that shape our society.

Over subsequent decades, CRT gained traction within legal scholarship and exerted its influence in diverse disciplines, including education, sociology, and political science. For example, Richard Delgado and Jean Stefancic's *Understanding Words That Wound* explored the impact of hate speech on marginalized communities.[54]

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50. The concept of interest convergence was further developed in Derrick Bell*, Brown v. Board of Education and the Interest-Convergence Dilemma,* 93 HARV. L. REV. 518 (1980). Bell describes how the interests of the White majority converged with desegregation to produce the decision in *Brown*. *Id.* at 518.

51. *See* Kimberlé Crenshaw, *Demarginalizing the Intersection of Race and Sex: A Black Feminist Critique of Antidiscrimination Doctrine, Feminist Theory and Antiracist Politics*, 1989 U. CHI. LEGAL F. 139, 167 (1989) [hereinafter Crenshaw, *Demarginalizing the Intersection of Race and Sex*].

52. *Kimberlé Crenshaw on Intersectionality, More than Two Decades Later*, COLUM. L. SCH. (June 8, 2017), https://www.law.columbia.edu/news/archive/kimberle-crenshaw-intersectionality-more-two-decades-later.

Crenshaw first introduced "intersectional" ideas to feminist and antiracist theory and politics in her 1989 article, *Demarginalizing the Intersection of Race and Sex: A Black Feminist Critique of Antidiscrimination Doctrine, Feminist Theory and Antiracist Politics*, *supra* note 51. Two years later, she extended her analysis by employing intersectionality to highlight the ways in which social movement organization and advocacy around violence against women elided the vulnerabilities of women of color, particularly those from immigrant and socially disadvantaged communities. Kimberlé Crenshaw, *Mapping the Margins: Intersectionality, Identity Politics, and Violence Against Women of Color*, 43 STAN. L. REV.1241 (1991).

54. RICHARD DELGADO & JEAN STEFANCIC, UNDERSTANDING WORDS THAT WOUND (2004).

More recently, CRT garnered widespread attention and ignited political controversies. *The New York Times Magazine*'s undertaking that culminated in *The 1619 Project* delved into the lasting legacy of slavery in America, prompting conservative criticism alleging distortion of historical truth.[55] The murder of George Floyd in 2020 and the subsequent racial justice protests thrust CRT into the forefront of public discourse,[56] as conservative politicians sought to prohibit the teaching of CRT in schools, utilizing it as a rallying point to mobilize their base.[57]

Within the realm of CRT scholarship, a critical stance has been taken against the objectivity paradigm that dominates empirical social sciences. A number of scholars in the field resist formulating fundamental ideas or a precise methodology. Crenshaw, for example, suggests that CRT should be viewed as a verb rather than a noun to emphasize that it is "dynamically constituted" as an evolving process of critique rather than a doctrine or ideology.[58] Others have emphasized that the individual person is ontologically prior to race, which is a social construction.[59] There is a tension here between denying the ontology of race and affirming the existence of race as an epistemological value.[60]

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55. NIKOLE HANNAH-JONES, THE 1619 PROJECT: A NEW ORIGIN STORY (2021); *see* Adam Serwer, *Why Conservatives Want to Cancel the 1619 Project*, ATLANTIC (May 21, 2021), https://www.theatlantic.com/ideas/archive/2021/05/why-conservatives-want-cancel-1619-project/618952/.

56. Victor Ray, *Critical Race Theory's Merchant of Doubt*, TIME (Aug. 1, 2022), https://time.com/6202664/critical-race-theorys-merchants-of-doubt/. *See generally* ROBERT SAMUELS & TOLUSE OLORUNNIPA, HIS NAME IS GEORGE FLOYD: ONE MAN'S LIFE AND THE STRUGGLE FOR RACIAL JUSTICE (2022); Toluse Olorunnipa, *George Floyd*, ENCYC. BRITANNICA, https://www.britannica.com/biography/George-Floyd (Mar. 23, 2024).

57. Marisa Iati, *What Is Critical Race Theory, and Why Do Republicans Want to Ban It in Schools?*, WASH. POST (May 29, 2001), https://www.washingtonpost.com/education/2021/05/29/critical-race-theory-bans-schools/.

58. Crenshaw, *Twenty Years*, *supra* note 11, at 1261.

59. "While philosophers and scientists have reached the consensus against racial naturalism, philosophers nevertheless disagree on the possible ontological status of a different conception of race." Michael James & Adam Burgos, *Race*, STAN. ENCYC. PHILOSOPHY, https://plato.stanford.edu/entries/race/#:~:text=The%20concept%20of%20race%20has,such%20that%20all%20and%20only (May 25, 2020).

60. For example, Devon W. Carbado notes:

> To put the point more doctrinally, race-based governmental decision-making must survive strict scrutiny. The baseline effects of whiteness, and the sameness/difference dynamic it produces, provides a *partial* explanation for why this is so. Because we are all (supposed to be) the same as whites—because race is ostensibly nothing but a skin-color—judges should "strictly scrutinize" instances in which the government

Scholars who are sympathetic to post-structuralist philosophers, notably Jean Francois Lyotard, Michel Foucault, and Jacques Derrida, reveal this tension when they argue for the unique knowledge derived from their experiences. For example, Richard Delgado and Jean Stefancic, in their seminal work, *Critical Race Theory: An Introduction*, emphasize the concept of a "unique voice of color."[61] They posit that writers and thinkers from Black, Indigenous American, Asian American, and Latinx backgrounds possess a distinct ability to understand and communicate matters that white individuals are unlikely to grasp due to their different histories and experiences of oppression.[62] Minority status thus confers a presumed competence to speak on matters of race and racism. This epistemic privilege stems from the belief that subjective, lived experiences are intrinsic to a shared communal-cultural knowledge. An implication of the claim that knowledge emerges from lived experiences

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> treats us differently by relying on race. At the same time, because we (people of color) are said to have different racial experiences than whites and this difference is perceived to facilitate the "robust exchange of ideas," the government may at least in the context of higher education, invoke diversity to justify relying on race.

Carbado, *Critical What What?*, *supra* note 11, at 1611–12 (citations omitted).

61. RICHARD DELGADO & JEAN STEFANCIC, CRITICAL RACE THEORY: AN INTRODUCTION 11 (4th ed. 2017) (outlining one objective of CRT as developing a voice).

62. Carbado explains,

> This critique [of empiricism] focuses on the way in which the language and theoretical method used to frame an inquiry shape not just the observer's interpretation of facts but also what the observer perceives to be a fact in the first place. For example, CRT scholars have argued that the observer's subject position shapes whether she views fleeing the police as evasive behavior (and thus evidence of wrongdoing) or behavior to avoid potential police brutality. Community knowledge or personal experience of how the police operate shapes the choice between these two frames . . . .
>
> Perceiving the researcher to be detached and neutral is potentially at odds with a crucial starting point of CRT: the idea that knowledge production is contingent on the combined effects of the researcher, the social and political contexts in which she is situated, and the inquiries and frameworks she employs.

Carbado, *Critical Race Theory Meets Social Science*, *supra* note 6, at 158–59 (first citing Devon Carbado, *(E)racing the Fourth Amendment*, 100 MICH. L. REV. 947 (2002); and then citing PATRICIA J. WILLIAMS, THE ALCHEMY OF RACE AND RIGHTS (1992)).

is that it often defies reducibility to verbal expression. In this analysis, objectivity (in the sense of meaning an observer detached from subjective biases) misses the value of lived experience in shaping the meaning of experience. For Delgado, narratives and counter-narratives ("storytelling") are indispensable means of conveying the meaningful experiences of marginalization and oppression.[63] Through storytelling, the intricate relationship between knowledge, language, and power, concealed within the confines of empiricism, finds expression. While not a defined method, opening the construction of identity to the realm of narrative allows persons to have some agency over their own identity.

B. The Conflict Between Claims of Objectivity and CRT's Assertion of Embedded Power Dynamics

1. Objectivity in Social Science

In the social sciences, objectivity is a cherished value with a long and distinguished lineage.[64] It is valued because it reflects the importance attached to certainty in our beliefs, and by valuing it, researchers signify their approval of it.[65] Objectivity, however, exists along a spectrum, with claims, methods, results, and scientists varying in their degree of objectivity.[66] All else being equal, greater objectivity is deemed preferable. Moreover, the term "objective" possesses a unique rhetorical power, contributing significantly to the widespread admiration of science among the public and the authority science

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63. Delgado writes,

> Literary and narrative theory holds that each occupies a normative universe or "nomos" (or perhaps many of them), from which we are not easily dislodged. Talented storytellers nevertheless struggle to reach broad audiences with their message. "Everyone loves a story." The hope is that well-told stories describing the reality of black and brown lives can help readers bridge the gap between their world and those of others. Engaging in stories can help understand what life is like for others and invite the reader into a new and unfamiliar world.

DELGADO & STEFANCIC, *supra* note 61, at 49.

64. Reiss & Sprenger, *supra* note 16.

65. *Id.*

66. For a discussion of the range of possibilities for objectivity in the social sciences, see DANIEL LITTLE, NEW DIRECTIONS IN THE PHILOSOPHY OF SOCIAL SCIENCE 249–50 (2016).

commands in society.[67] Comprehending the concept of scientific objectivity is therefore pivotal to understanding the essence of social science and its societal role. If science's merit lies in its objectivity, then objectivity itself must warrant a staunch defense. Nonetheless, "[t]he close examinations of scientific practice that philosophers of science have undertaken in the past fifty years have shown, however, that several conceptions of the ideal of objectivity are either questionable or unattainable."[68] For instance, the prospects of social science offering a non-perspectival "view from nowhere" or proceeding devoid of human goals and values are slim.[69] Various proposals aim to characterize the concept and ideal of objectivity in a manner that strikes a balance: being robust enough to possess value and yet feasible and practical in application.

The concept of objectivity, at its core, entails the capacity to approach the investigation of human behavior and societal phenomena without succumbing to personal biases, preconceptions, or external influences.[70] Within the contemporary landscape of abundant data and diverse perspectives, the preservation of objectivity assumes an ever-heightened importance. While it is a contested concept, objectivity remains an influential facet of social science in this era of copious information.

Despite the rigor and ambition of early twentieth century philosophy, the foundations of knowledge were never achieved. It was a time of dramatic change that displaced many long-held beliefs about mathematics, logic, human nature, the nature of space and time, and the moral meaning of human experience.[71] Fundamental to these changes

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67. Reiss & Sprenger, *supra* note 16.

68. *Id.*

69. *See id.*

70. *Id.* ("[Objectivity] expresses the idea that scientific claims, methods, results—and scientists themselves—are not, or should not be, influenced by particular perspectives, value judgments, community bias or personal interests, to name a few relevant factors. Objectivity is often considered to be an ideal for scientific inquiry, a good reason for valuing scientific knowledge, and the basis of the authority of science in society.").

71. For a history of twentieth century philosophy, see A.J. AYERS, PHILOSOPHY IN THE TWENTIETH CENTURY (1981). For a history of mathematics, see WILLIAM KNEALE & MARTHA KNEALE, THE DEVELOPMENT OF LOGIC (1984). For an introduction to the development of the philosophy of science, see PETER GODFREY-SMITH, THEORY AND REALITY: AN INTRODUCTION TO THE PHILOSOPHY OF SCIENCE (2021). HELGE KRAGH, QUANTUM GENERATIONS (rev. 2020) is an introduction to the history of physics in the twentieth century, focusing on the political and cultural milieu of the physicists' work.

were new theories of logic and mathematics that challenged traditional beliefs about the foundations of knowledge. Questions concerning the foundations of geometry, mathematics, and logic eroded confidence in classical and medieval understandings.[72] The resulting crisis led some of the greatest minds in Europe to attempt to find new foundations for mathematical and scientific knowledge. Rather than naïvely relying on causal observations as the foundation for truth, which had been the foundation for classical and medieval mathematics and logic, the twentieth century approach focused on grounding knowledge in rigorously analyzed formal axioms.[73] The process of formalization involved encoding mathematical concepts and reasoning into symbolic logic and axiomatic systems, enabling rigorous manipulation and deduction of mathematical statements. The turn to formalized mathematics played a crucial role in the development of the information age by providing a theoretical and logical foundation for the construction and analysis of computational systems.[74] The formalization of mathematics developed into the concept of algorithms—step-by-step

72. For an introduction to these developments, see MARCUS GIAQUINTO, THE SEARCH FOR CERTAINTY (2004).

73. Øystein Linnebo explains that,

> Following the discovery of non-Euclidean geometry, the link between geometry and physical space was abandoned in favor of Hilbert's more abstract approach, which regards geometry as the study of any system of objects structured in some appropriate and loosely 'spacelike' manner. An analogous development took place in algebra, where theories of algebraic structures each as groups, rings, and fields were formulated with the explicit aim of *not* having a particular interpretation. The aim was instead to characterize some important classes of structures that have multiple realizations throughout mathematics and perhaps also in the physical world.

ØYSTEIN LINNEBO, PHILOSOPHY OF MATHEMATICS 155 (2017). A lengthy discussion of the shift from naïve realism to formalism can be found in Kevin P. Lee, *The Conceptions of Self-Evidence in the Finnis Reconstruction of Natural Law,* 51 ST. MARY'S L.J. 413 (2020). *See also* LUKE HEATON, A BRIEF HISTORY OF MATHEMATICAL THOUGHT 167–98 (2017); KNEALE & KNEALE, *supra* note 71, at 379–83.

74. An accessible introduction to information science and the precursor to it can be found in JAMES GLEICK, THE INFORMATION (2012). Shannon's theory of information separated "meaning" from linquistic form and then considered the logical structure that remained *Id.* at 219. The development and utility of Shannon's theory was furthered by the development of the computer, which was invented by Alan Turing while working on one of the problems of David Hilbert program for the formalization of mathematics *Id.* at 206

procedures for solving problems.[75] Instead of certain foundations, however, close analysis led to paradox and the impossibility of comprehensive foundations. For example, Bertrand Russell's paradox challenged the foundations of set theory,[76] and Kurt Gödel's incompleteness theories suggested that assumptions are unavoidable.[77] The rigorous analysis of the observed world did not lead back to stable, foundational truths, but opened to a new view of reality that rejected metaphysical essences and fixed geometries. Uncertainty, rather than certainty, appeared to be the fundamental order of reality. The hope of the Enlightenment was to find the foundational claims that justify true belief (foundationalism), yielded to the lack of certainty—to warranted but not justified belief.[78] New approaches to epistemology (coherentism,[79] evidentialism,[80] and reliabilism[81]) were advanced to describe how knowledge is possible with warranted beliefs that did not rely on certain foundations.

In the early twentieth century, the works of Max Weber[82] and Nelson Goodman[83] were influential in the philosophy of the social

75. *See* THOMAS H. CORMEN, CHARLES E. LEISERSON, RONALD L. RIVEST, & CLIFFORD STEIN, INTRODUCTION TO ALGORITHMS 5 (2d ed. 2001).

76. For an introduction to Russell's paradox, see Andrew Irvine & Harry Deutsch, *Russell's Paradox*, STAN. ENCYC. PHILOSOPHY, https://plato.stanford.edu/archives/spr2021/entries/russell-paradox/ (Oct. 10, 2020).

77. For an introduction to Gödel's incompleteness theorems, see ERNEST NAGEL & JAMES R. NEWMAN, GÖDEL'S PROOF (Douglas R. Hofstadler ed., N.Y.U. Press rev. ed., 2001); REBECCA GOLDSTEIN, INCOMPLETENESS: THE PROOF AND PARADOX OF KURT GÖDEL (2005). For biographical background on Gödel, see JOHN CASTI & WERNER DEPAULI, GÖDEL: A LIFE OF LOGIC (2000); STEPHEN BUDIANSKY, JOURNEY TO THE EDGE OF REASON: THE LIFE OF KURT GÖDEL (2021).

78. For a discussion of knowledge as "justified true belief," see Jonathan Jenkins Ichikawa & Matthias Steup, *The Analysis of Knowledge*, STAN. ENCYC. PHILOSOPHY, https://plato.stanford.edu/archives/sum2018/entries/knowledge-analysis/ (Mar. 7, 2017). For a discussion of "warranted true belief," see Peter D. Klein, *Warrant*, *in Knowledge, Concept of*, ROUTLEDGE ENCYC. PHILOSOPHY., https://www.rep.routledge.com/articles/thematic/knowledge-concept-of/v-1/sections/warrant (last visited Jan. 24, 2024).

79. *See* Erik Olsson, *Coherentist Theories of Epistemic Justification*, STAN. ENCYC. PHILOSOPHY, https://plato.stanford.edu/entries/justep-coherence/ (Mar. 9, 2021).

80. *See* KEVIN MCCAIN, EVIDENTIALISM AND EPISTEMIC JUSTIFICATION 1–2 (2014).

81. *See* Alvin Goldman & Bob Beddor, *Reliabilist Epistemology*, STAN. ENCYC. PHILOSOPHY, https://plato.stanford.edu/archives/sum2021/entries/reliabilism/ (May 1, 2021).

82. *See* WOLFGANG SCHLUCHTER, THE RISE OF WESTERN RATIONALISM: MAX WEBER'S DEVELOPMENTAL HISTORY 25 (Guenther Roth trans., 1981); Sung Ho Kim, *Max Weber*, STAN. ENCYC. PHILOSOPHY, https://plato.stanford.edu/archives/win2022/entries/weber/ (Sept. 21, 2022).

sciences.[84] They delineate some themes that were influential in structuring the discourse about knowledge for social scientists. Daniel Little has provided a useful summary of some of their major theses of the literature on objectivity:

1. *Ontological objectivity*. This entails positing the independent existence of a social world that transcends the concepts and theories formulated by scientists. This perspective intimates that social phenomena unveil underlying causally ordered processes that are susceptible to discovery and comprehension.[85]

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83. For an introduction to Nelson Goodman, see Catherine Z. Elgin, *The Legacy of Nelson Goodman*, 62 PHIL. & PHENOMENOLOGICAL RSCH. 679–90 (2001).

84. This section of the essay is indebted to LITTLE, *supra* note 12.

85. LITTLE, *supra* note 12, at 249. In scientific discourse, objectivity embodies the notion that scientific assertions, methodologies, outcomes, and even the scientists themselves should remain uninfluenced by specific perspectives, value judgments, communal biases, personal interests, and other pertinent factors. Reiss & Sprenger, *supra* note 16. Objectivity is commonly regarded as "an ideal for scientific inquiry," providing a compelling rationale for esteeming scientific knowledge and serving as the foundation of science's authority in society. *Id.*

> In the philosophy of social science . . . there is a gulf in terms of both goals and methods of natural and the social sciences. This tradition, associated with thinkers such as the neo-Kantians Heinrich Rickert and Wilhelm Windelband, the hermeneuticist Wilhelm Dilthey, the sociologist-economist Max Weber, and the twentieth-century hermeneuticists Hans-Georg Gadamer and Michael Oakeshott, holds that, unlike the natural sciences whose aim it is to establish natural laws and which proceed by experimentation and causal analysis, the social sciences seek understanding ("*Verstehen*") of social phenomena, the interpretive examination of the meanings individuals attribute to their actions . . . . Understood this way, social science lacks objectivity in more than one sense. One of the more important debates concerning objectivity in the social sciences concerns the role value judgments play and, importantly, whether value-laden research entails claims about the desirability of actions. Max Weber held that the social sciences are necessarily value laden. However, they can achieve some degree of objectivity by keeping out the social researcher's views about whether agents' goals are commendable. In a similar vein, contemporary economics can be said to be value-laden because it predicts and explains social phenomena on the basis of agents' preferences. Nevertheless, economists are adamant that they are not in the business of telling people what they ought to value. Modern economics is thus said to be objective in the Weberian sense of "absence of researchers" values . . . .
>
> *Id.*

2. *Epistemic objectivity*. This contends that a theory attains objectivity when its justification is derived from the deployment of scientific methods, disentangled from personal biases and subjective value perspectives. The pursuit of objectivity necessitates a comparative evaluation of competing theories, engagement with objective procedures, and the presentation of empirical and logical arguments that advocate for one theory over its rivals.[86]

3. *The autonomy of social facts.* The thesis that social facts are distinguishable from the conscious states of individuals involved demarcates materialist social science, centered on objective facts, from interpretation theory and *verstehen* sociology, which accentuates the subjective meanings ascribed by participants.[87]

4. *Detachment from subjective values and interests*. While scientific research remains inevitably influenced by the intellectual and moral predispositions of the investigator, it is argued that value commitments can be extricated from scientific conduct. This viewpoint aligns with Max Weber's position expounded in "Objectivity in Social Science."[88]

5. *Consensus*. The fifth thesis asserts that scientific inquiry tends to converge towards consensus among researchers through further empirical and theoretical investigations. The attainment of consensus is regarded as a manifestation of heightened agreement and indicative of progress in scientific understanding.[89]

These theses collectively challenge conceptual relativism and the underdetermination arguments prevalent in some philosophical writings that are foundational for CRT.

Various permutations of these theses have shaped the discourse on epistemology in the social sciences. Weber acknowledges the existence of social facts (thesis 1), albeit considering them subjective in nature (thesis 3).[90] He simultaneously accepts the potential for well-grounded descriptions of these facts (thesis 2).[91] In contrast, Goodman repudiates the notion of a singular objective social world (thesis 1) and

86. LITTLE, *supra* note 12, at 249–50.
87. *Id.*
88. *Id.*
89. *Id.*
90. *Id.*
91. *Id.*

rejects the possibility of a uniquely optimal theory (thesis 2).[92] The form of objectivity in social science upheld by Goodman embraces the existence of objective social facts (thesis 1) alongside the potential for well-grounded theories (thesis 2).[93] It posits that the social world exhibits both material and subjective dimensions, with the convergence of theoretical beliefs (thesis 5) realizable through the internal mechanisms inherent in social science disciplines.[94] Understood in this way, the concept of objectivity in the realm of social science pervades discussions, evoking profound inquiries into the existence of autonomous social facts and phenomena that can be investigated and comprehended through scientific methodologies. A theory's claim to represent an objective scientific analysis of social phenomena presupposes a solid grounding in empirical evidence and rigorous theoretical reasoning. The question of objectivity within the realm of social science is a subject of ongoing debate, evoking profound philosophical contemplation and igniting intellectual inquiries into the nature of independent social facts and phenomena that can be subject to rigorous scientific examination.[95] Acknowledging the inherent influence of interests and normative commitments in scientific research, proponents of objectivity, akin to Weber, argue that biased factors do not undermine the possibility of objectivity. Upon the delineation of the research program, the possibility of achieving an objective analysis of the subject matter might endure. The discourse surrounding objectivity within social science arises from a nexus of interwoven theses, illuminating the multifaceted nature of the debate.[96]

2. Data Science and Objectivity

Data science presents particular variations on the general themes of the epistemology discourse. While the field of data science has emerged as a vital tool for extracting valuable insights from the vast amounts of data available, the notion of objectivity in data science is a

92. *Id.*
93. *Id.*
94. *Id.*
95. *Id.* at 249–51.
96. *Id.*

subject that has received growing concern.[97] As data plays an increasingly significant role in decision-making processes across various sectors, it is crucial to examine how biases occur in particular cases and what challenges permeate the field of data analysis. Several patterns of issues have emerged and been widely recognized in the literature on race and justice. For example, many scholars question the possibility of objective data.[98] They argue that data, by its nature, is inherently subjective.[99] It is collected, processed, and interpreted by human beings who are susceptible to conscious and unconscious biases.[100] These biases can manifest at different stages of the data science pipeline, including data collection, preprocessing, feature selection, algorithm design, and interpretation of results.[101] Acknowledging this inherent subjectivity is a crucial step towards understanding the complexities of objectivity in data science. Some sources of bias in data include:

1. *Sampling bias.* The process of data collection can introduce biases if the sample is not representative of the population of interest.[102] Biased sampling can result in skewed or incomplete datasets, leading to erroneous conclusions.[103]

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97. For an overview of this expansive topic, see MELANIE FEINBERG, EVERYDAY ADVENTURES WITH UNRULY DATA (2022).

98. *See, e.g.*, RUHA BENJAMIN, RACE AFTER TECHNOLOGY 48 (2019) ("[W]henever we hear the promises of tech being extolled, our antennae should pop up to question what all that hype of 'better, faster, fairer' might be hiding and making us ignore. And, when bias and inequity come to light, 'lack of intention' to harm is not a viable alibi. One cannot reap the reward when things go right but downplay responsibility when they go wrong.").

99. *Id.* at 16; FEINBERG, *supra* note 97, at 242.

100. FEINBERG, *supra* note 97, at 242.

101. *Id.*

102. Stefano Panzeri, Cesare Magri, & Ludovico Carraro, *Sampling Bias*, SCHOLARPEDIA, http://www.scholarpedia.org/article/Sampling_bias (last visited Jan. 31, 2024).

103. *APA Dictionary of Psychology*, *Sampling Bias*, AM. PSYCH. ASS'N, https://dictionary.apa.org/sampling-bias (Apr. 19, 2018). As Safiya Umoja Noble puts it, "We need people designing technologies for society to have training and an education on the histories of marginalized people, at a minimum, and we need them working alongside people with rigorous training and preparation from the social sciences and humanities." SAFIYA UMOJA NOBLE, ALGORITHMS OF OPPRESSION: HOW SEARCH ENGINES REINFORCE RACISM 70 (2018); *see also* Bredesha M. Tynes, Joshua Schuschke, & Safiya Umja Noble, *Digital Intersectionality Theory and the #Blacklivesmatter Movement*, *in* THE INTERSECTIONAL INTERNET: RACE, SEX, CLASS, AND CULTURE ONLINE 21, 21–40 (Safiya Umja Noble & Bredesha M. Tynes eds., 2016).

2. *Algorithmic bias:* Machine learning algorithms can perpetuate biases present in the data they are trained on.[104] If historical data contain societal or systemic biases, algorithms can inadvertently reinforce these biases when making predictions or decisions.[105]

3. *Confirmation bias:* Data scientists may inadvertently favor findings that align with preconceived notions or hypotheses, inadvertently ignoring or downplaying contradictory evidence.[106] This confirmation bias can impact the objectivity of the entire analysis process.[107]

Other critiques of data science look to its role in furthering colonialist practices from the nineteenth century reflecting the classical concerns and offering fresh insight into them.[108]

3. Bayesian Epistemology

Given these features, data science has contributed to new thinking about knowledge, especially Bayesian epistemology.[109] This theory takes its name from Thomas Bayes (1702–61), an English mathematician and Presbyterian minister best known for his work in

104. Nima Kordzadeh & Maryam Ghasemaghaei, *Algorithmic Bias: Review, Synthesis, and Future Research Directions*, 31 EURO. J. INFO. SYS. 388, 388 (2021).

105. *See* CATHY O'NEAL, WEAPONS OF MATH DESTRUCTION: HOW BIG DATA INCREASES INEQUALITY AND THREATENS DEMOCRACY 15–31 (2016) (describing algorithmic bias).

106. Bettina J. Casad & J.E. Luebering, *Confirmation Bias*, ENCYC. BRITANNICA, https://www.britannica.com/science/confirmation-bias (Jan. 5, 2024).

107. *See* ALEX ACKS, THE BUBBLE OF CONFIRMATION BIAS 4–24 (2019); Paul E. Lehner, Leonard Adelman, Brant A. Cheikes, & Mark J. Brown, *Confirmation Bias in Complex Analyses*, 38 IEEE TRANSACTIONS ON SYSTEMS MAN AND CYBERNETICS 584, 584 (2008).

108. *See, e.g.*, NICK COULDRY & ULISES A. MEJIAS, THE COSTS OF CONNECTION (2019) (arguing that the global data economy foreshadows a new colonialism). Like Weber, data science assumes the existence of social facts (thesis 1), but it recognizes that social facts are inseparable from subjective judgments the contribute to sampling and algorithmic bias (thesis 3). *See supra* notes 86, 88 and accompanying text. Like Goodman, contemporary data science rejects the concept of a singular objective social world (thesis 1) and the possibility of an optimal theory (thesis 2). *See supra* notes 86–87 and accompanying text. It places value on social convergence as an epistemic value (thesis 5). *See supra* note 99 and accompanying text; LITTLE, *supra* note 12, at 250–51.

109. For a mathematical introduction to Bayesian probability, see JAMES V. STONE, BAYES' RULE: A TUTORIAL INTRODUCTION TO BAYESIAN ANALYSIS (2013).

probability theory and inference.[110] His most significant contribution, "An Essay towards solving a Problem in the Doctrine of Chances," published posthumously in 1763, laid the foundation for what is now known as Bayesian probability theory.[111] In this essay, Bayes introduced a theorem that provided a method for revising probabilities based on new evidence.[112] This theorem, which became known as Bayes's theorem, allows for the calculation of conditional probabilities by combining prior probabilities with the likelihood of observed data.[113] The key idea is that beliefs should be assigned probabilities based on the available evidence and updated in a rational and coherent manner.[114] Bayesian reasoning involves assigning prior probabilities to different hypotheses, evaluating the likelihood of the observed evidence under each hypothesis, and combining these to calculate the posterior probabilities.[115] Bayes's theory provides a formal and systematic approach for updating beliefs in light of new information, and has had a profound impact on various fields, including statistics, artificial intelligence, machine learning, and philosophy of science.[116] Today, Bayesian statistics are widely used and form an essential part of contemporary statistical and probabilistic reasoning with complicated ties to Kolmogorov information, Bayesian probability, and modeling complex systems.[117] Kolmogorov information as an interpretation of complex systems is discussed below.[118]

C. The Epistemic Gap

Empiricism and critical race theory draw from different assumptions about what knowledge is and how it can be obtained, if at all. This difference constitutes a theoretical gap between the two

110. For biographical information, see *Thomas Bayes*, ENCYC. BRITANNICA https://www.britannica.com/biography/Thomas-Bayes (Jan. 1, 2024).

111. *See id.* For historical background on Bayesian analysis, see Hanti Lin, *Bayesian Epistemology*, STAN. ENCYC. PHILOSOPHY (June 13, 2022), https://plato.stanford.edu/archives/fall2022/entries/epistemology-bayesian/.

112. Lin, *supra* note 111.

113. *Id.*

114. *Id.*

115. *Id.*

116. *Id.*

117. *Id.*

118. *See infra* notes 189–97 and accompanying text.

theories. Implicit in the hopes of an empirical CRT is the expectation that this gap can be closed, so that the two approaches to knowledge can be rendered compatible. While empiricism and CRT treat the status of the independent observer differently, the gap between them is neither theoretically nor historically absolute. They are much more closely related than is commonly understood. Some insight into this misunderstood closeness can be found in *Code*, *From Information Theory to French Theory* by Bernard Dionysius Geoghegan.[119] In this book, Geoghegan explores the political and intellectual history of cultural theory from the 1930s to the 1970s. Of particular interest is the discussion of the relationship between cybernetics and structuralism.[120] At its core, cybernetics delves into the intricate study of control and communication systems, employing concepts such as information feedback, circular causality, equilibrium states, and automatic governance.[121] An exemplary embodiment of these principles can be found in the humble thermostat, diligently maintaining a set temperature by continuously adjusting its mechanisms based on feedback readings. Yet, the cyberneticians of the mid-twentieth century aspired to transcend these mundane applications, envisioning cybernetics as a science capable of providing solutions for nearly everything.[122] Pioneers in this field, notably Norbert Weiner, sought to weave a tapestry of interconnected systems, embracing realms as diverse as mechanics (exemplified by thermostats), digital networks, biological entities (such as nervous systems), psychological phenomena (including mental illness), cultural interactions, social dynamics (within families), political structures (such as government planning), organizational frameworks (including corporate management), and much more.[123] Weiner believed that all of these arenas possessed a cybernetic essence, rendering them subject to the overarching influence of the cybernetician.[124]

The conventional narrative surrounding the birth of cybernetics often links its origins to the ambitions of military engineering during

119. BERNARD DIONYSIUS GEOGHEGAN, CODE: FROM INFORMATION THEORY TO FRENCH THEORY (2023).

120. *Id.* at 120–22.

121. *Cybernetics*, ENCYC. BRITANNICA, https://www.britannica.com/science/cybernetics (Feb. 24, 2024).

122. GEOGHEGAN, *supra* note 119, at 2–3.

123. MITCHELL, *supra* note 29, at 296–97.

124. GEOGHEGAN, *supra* note 119 at 1–2.

World War II, which later expanded into a sprawling technocratic apparatus.[125] However, Geoghegan contends that the true progenitors of cybernetics were to be found within "a landscape of cultural and political crises that drove their efforts to master the unruliness of human communications with technical expertise."[126] He traces the rich lineage of luminous figures spanning anthropology, psychology, linguistics, philosophy, and literary criticism, whose commitment to the cybernetic movement dates back as far as the 1930s.[127] These names—Margaret Mead, Gregory Bateson, Claude Shannon, Roman Jakobson, Claude Lévi-Strauss, Marcel Mauss, Roland Barthes, and Jacques Lacan—now occupy prominent positions within disciplinary canons, their contributions etched indelibly upon intellectual history.[128] For instance, Bateson, working alongside colleagues in the Palo Alto Group, integrated cybernetics into his endeavors exploring cognitive behavioral interventions for family psychotherapy.[129]

Of particular significance for the development of cultural theory, the anthropologist Claude Lévi-Strauss, renowned for his extensive work in ethnography and the anthropology of law,[130] ingeniously merged his research with cybernetic theories of systems dynamics, ultimately advocating for technocratic methods of administration during his influential tenure at UNESCO.[131] Geoghegan discerns a profound link between information theory and French theory, artfully traced through the trajectories of these notable figures.[132] The shift from the structuralist perspective of "culture as communication" to the cybernetic outlook of "culture as code" encapsulates the intellectual current that flows through their collective contributions.[133] This new approach drove Lévi-Strauss to champion technocratic methods of

125. *See id.* at 2. For a standard account, see, e.g., Asterios G. Kefalas, *Cybernetics*, *in* ENCYCLOPEDIA OF INFORMATION SYSTEMS, VOL. 1, at 365 (2003).

126. For a standard account, see GEOGHEGAN, *supra* note 119, at 4.

127. *See id.* at 3–5.

128. *See id.* at 5–6.

129. *Id.* at 53–55.

130. For Lévi-Strauss's contributions to anthropology, see JAMES A. BOON, FROM SYMBOLISM TO STRUCTURALISM: LÉVI-STRAUSS IN A LITERARY TRADITION (1972).

131. GEOGHEGAN, *supra* note 119, at 107–28 (discussing Lévi-Strauss's development of technocratic methods during his tenure at UNESCO).

132. *Id.* at 107–22.

133. *Id.* at 134–36.

administration during his tenure at UNESCO.[134] His multifaceted engagement with cybernetics and its far-reaching implications offers a compelling testament to the potency of his interdisciplinary inquiry. Of particular relevance, Geoghegan shows how cybernetics influenced French semiotics. He explains that during the 1960s, French cultural critics affiliated with *Tel Quel* and *Communications*, two prominent journals, incorporated elements of Roman Jakobson's and Lévi-Strauss's cybernetic structuralism into French Marxist critiques. A key figure in this history is Russian linguist, Roman Jakobson, who advocated for the structuralism of Ferdinand de Saussure.[135] This amalgamation contributed to French semiotics, an experimental form of writing that encompassed both scientific and artistic realms. By employing cybernetic tropes and problematics, this mode of writing aimed to thematize the historical and political foundations of communication and science.[136] For example, in his 1961 essay "*Le Message Photographique*," Roland Barthes reinterpreted Jakobson's and Shannon's schematic model of communication to forge new approaches in critical and historical analysis.[137] Barthes claimed, "every semiotic code is simultaneously arbitrary and rational . . . [resorting] to a code is thus always an opportunity for man to prove himself, to test himself through a reason and a liberty."[138] "In this sense, the analysis of codes perhaps allows an easier and surer historical definition of a society than the analysis of its signifieds."[139] Embracing this line of thought, Jacques Derrida, in his seminal work "*De la grammatologie*" posited that the "nonfortuitous" convergence between the human sciences and cybernetics represented the contemporary embodiment of how Western science was deconstructing its own logos.[140] And Julia Kristeva drew upon Wiener's research on models as a resource for developing a "science of critique" that would coincide with a "critique of science," specifically targeting scientists' attempts to impose simple rules on a chaotic world through orderly models, the very same critique

134. *Id.* at 122–29.
135. *Id.* at 153.
136. *Id.* at 155–56.
137. *Id.* at 158–64.
138. *Id.* at 160.
139. *Id.* at 161.
140. *Id.* at 134–36.

brought by complexity science.[141] Rather than a divide between cybernetics and French thought, Geoghegan shows mutuality in interests and approach, and a mutual willingness to utilize the concepts of representation, code, and concealed order to transform writing into an experimental system for probing the politics and historicity of scientific discourse and communication.

To summarize the argument being made here: with the insightful history of the relationship between cybernetics and critical theory in hand, the relationship between empirical science and CRT should be reconsidered. CRT, with its decades-long existence and connections to critical theory and post-structuralism, has provided a critical framework through which the social and legal construction of race can be exposed. It highlights the systemic semiotic nature of racial subordination and exposes the unintended racial meaning of legal mechanisms, even those designed to combat discrimination. These insights have been profound, but the methodologies employed in substantiating them have not always been as aware and rigorous as is desired by quantitative social sciences. CRT often focuses on internal inconsistencies and narratives that expose the fallacies of representation or offers historical and theoretical critiques that, while important, lack a measurable basis for understanding the depth of on-the-ground trends and social dynamics. Conversely, social scientists have honed sophisticated statistical and qualitative tools to measure the complexities of the social world but paid insufficient attention to the cultural construction of their tools and foundational assumptions. They have developed probabilistic measures and qualitative analyses that illuminate the subtle human dynamics shaping our daily lives. To CRT theorists, the epistemology of social science is muddled in subjective judgments that are the result of cultural biases. To social scientists, critical race theorists are vague and form judgments without careful examination of evidence and methodical reasoning. The history developed by Geoghegan suggests that common ground exists between CRT and empiricism in the concepts of representation, revision, and the limits of knowledge. Representation for complexity science and CRT is always contextual and shaped by culture and random historical events. They agree that contingency and probability are epistemic values, and

141. *Id.* at 164–65.

that lived experience might supplement technical analysis for insights into meaning. Also, aspects of social behavior are nomological—they are regular and consistent even while being unfathomable in their origins and meaning. The epistemic values between these two very different approaches reflect the intimate history between them that Geoghegan proposes.

It is not surprising, then, that some scholars see hope for a future in which the epistemological divide is softened. For example, in the foreword to a symposium on empirical critical race theory, the noted bioethicist and law professor Osagie Obasogie illuminates the current juncture at which CRT and empirical research on race find themselves.[142] Both disciplines have made valuable contributions, yet they face distinct challenges. Obasogie argues that in the midst of this juxtaposition lies an exceptional opportunity to forge an alliance between social science methodologies and critical race theory.[143] Such an alliance would cultivate a race scholarship that is simultaneously theoretically sophisticated and empirically robust. It beckons us to conceive and quantify race in novel and exhilarating ways, harnessing the strengths of multiple disciplines to investigate, document, and theoretically extrapolate the covert interplay between law, society, and race. This endeavor builds upon previous calls for an expanded race scholarship, with scholars such as Laura Gómez,[144] Gregory S. Parks,[145] Osagie K. Obasogie,[146] Devon Carbado,[147] and others contemplating the profound prospects of integrating empirical research and CRT. They envision a sustained effort that initiates a new literary trajectory—one that constitutes an empirical intervention into CRT and a CRT intervention into empirical studies, as aptly noted by Carbado.[148]

142. Obasogie, *Forword*, *supra* note 4, at 184–85.

143. *Id.*

144. *See* Laura Gómez, *A Tale of Two Genres: On the Real and Ideal Links Between Law and Society and Critical Race Theory*, *in* THE BLACKWELL COMPANION TO LAW AND SOCIETY 453 (Austin Sarrat, ed., 2004); Laura Gómez, MANIFEST DESTINIES: THE MAKING OF THE MEXICAN AMERICAN RACE (2d ed., 2018); Laura Gómez, *Looking for Race in All the Wrong Places*, 46 L. & SOC. REV. 221 (2013).

145. *See* Gregory S. Parks, *Toward Critical Race Realism*, 17 CORNELL J. LAW & PUB. POL. 683 (2008).

146. *See* Obasogie, *Foreword*, *supra* note 4.

147. *See* Carbado, *Critical Race Theory Meets Social Science*, *supra* note 6.

148. *Id.*

Thus, the present moment is characterized by an imperative of uniting critical race theory and social science methodologies. This would allow scholars in the field to embark upon a transformative journey that elevates race scholarship to unprecedented heights. This endeavor encourages the exploration of uncharted territories, fusing theoretical acumen and narrative technique with empirical rigor. It beckons us to unveil the intricate interconnections between law, society, and race, fostering a comprehensive understanding of the world we inhabit. In forging this alliance, we strive to chart a new path, emboldened by the conviction that the integration of CRT and empirical research will lead us toward a more just and equitable future.

Complexity science appears to offer some hope on this path of forging alliances between social theory and empirical science. As the cybernetics and semiotic theorists found common ground in revealing hidden meaning and concealed social forces, complexity science views social systems as evolved and evolving entities with internal forces that can be difficult to detect, even with massive data and powerful computers equipped with the latest algorithms. Social systems are more like a living organism than a mechanism, as earlier Enlightenment social theorists like Auguste Comte believed.[149] It is not possible to control them with simple rules that were once sought by unsophisticated liberals, nor are they totally self-organized entities as conceived in the Austrian economics of Hayek.[150] Critically, as is explained below, as with any living thing, a social system is the result of a myriad of accidental events that contribute to the long history of the social system as a whole and each member of it. The history matters to understanding and predicting the behavior of social systems, and therefore no adequate understanding can be achieved apart from the narratives and counter-narratives that give texture and meaning to the bare bones of empirical analysis. To appreciate the significance of this view, some technical aspects of information science and complexity science must be considered.

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149. See Mitchell, *supra* note 29, at 115–16 (discussing life-like features of complex systems.) For an introduction to Auguste Comte, see Michel Bordeau, *Auguste Comte*, STAN. ENCYC. OF PHIL., https://plato.stanford.edu/archives/spr2023/entries/comte/ (Jan. 27, 2022).

150. *See* DAVID COLANDER & ROLAND KUPERS, COMPLEXITY AND THE ART OF PUBLIC POLICY: SOLVING SOCIETY'S PROBLEMS FROM THE BOTTOM UP 5, 39–41 (2022).

II. COMPLEXITY SCIENCE AND THE ALGORITHMIC INFORMATION INTERPRETATION

A. Information and Complex Systems

Complexity science has been interpreted through information science, which is the theory of communication that was pioneered by Claude Shannon in the mid-twentieth century.[151] An "information interpretation" of complex systems is critical to its influence in social science, so before going further into the significance of complexity for social science, it is useful to consider the basic claims of Shannon information theory, which is a means for estimating the successful transmission of a signal that holds implications for the basic structures of physical reality. It is the later claims about the nature of reality that have given rise to the philosophy of information.

1. Shannon Information Theory

Shannon's contribution to the information revolution began in the mid-twentieth century, when Bell Labs faced the challenge of expanding its service to remote areas of the country while coping with the noise introduced by lengthening transmission wires.[152] Shannon approached this problem as one of mathematical abstraction, paving the way for vast communication and computation systems that we rely on today. In his seminal paper, "A Mathematical Theory of Communication," published in *The Bell System Technical Journal* in 1948, Shannon introduced the concept of the "bit," the smallest unit of information, as the binary condition of an open or closed switch controlling telephones.[153] Although the idea of sending binary signals was not new, Shannon's mathematical description of information was revolutionary. Before Shannon, information referred to a psychological

151. *See* JIMMY SONI & ROB GOODMAN, A MIND AT PLAY: HOW CLAUDE SHANNON INVENTED THE INFORMATION AGE (2017).

152. Gleick, *supra* note 74, at 5. For a more technical introduction to Shannon Information, see generally *id.*; JAMES V. STONE, INFORMATION THEORY: A TUTORIAL INTRODUCTION (2018).

153. GLEICK, *supra* note 74, at 77; CLAUDE SHANNON & WARREN WEAVER, THE MATHEMATICAL THEORY OF COMMUNICATIONS (1971).

phenomenon that had to do with perception.[154] The mind was conformed to the world. Shannon's insight was to analyze the extraction of a signal from a noisy background.[155] He found that by separating the concept of "information" from psychological meaning, a measurable phenomenon associated with the amount of uncertainty of a system could be determined with great precision.[156]

Shannon's theory launched the science of information as the study of a formal physical process that can be mathematically described apart from the semantic meaning a signal might carry. The fundamental problem of information science is to determine the probability of a communication being received and reproduced as it is sent from one point to another, regardless of semantic meaning.[157] Information, in Shannon's theory, is a measure of a formal structure of communication.[158] Information adds certainty and reduces uncertainty in a transmission. In this regard, the measure of entropy can be described by a reduction in information.[159] And, indeed, "Shannon Entropy," as it came to be known, suggests that information entropy is related to the second law of thermodynamics, which describes the natural tendency of an isolated system to degenerate into a more disordered state.[160]

Today, Shannon's theory lies behind every digital device and is. in this way, a foundation for the technology-driven contemporary society. As data has become a commodity, bits of information—stored, transmitted, and processed—are the raw material for economic production.[161] Soon, quantum information theory may supersede

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154. *See, e.g*, Yehoshua Bar-Hillel and Rudolf Carnap, *Semantic Information*, 4 BRITISH J. PHIL. SCIENCE, 147–57 (1957) (arguing that semantic information had to do with "mind-directedness" or "intention").

155. GLEICK, *supra* note 74, at 218–21.

156. *Id.* at 224–31.

157. G. Markowsky, *Information theory*, ENCYC. BRITANNICA, https://www.britannica.com/science/information-theory (Dec. 15, 2023) ("A key step in Shannon's work was his realization that, in order to have a theory, communication signals must be treated in isolation from the meaning of the messages that they transmit. This view is in sharp contrast with the common conception of information, in which meaning has an essential role.").

158. GLEICK, *supra,* note 74, at 269–72.

159. *Id.* at 269–72.

160. *Id.* at 269–86.

161. For an extended analysis of the information economy, see SHOSHANA ZUBOFF, THE AGE OF SURVEILLANCE CAPITALISM (2019).

Shannon's conventional theory. Quantum computing introduced novel concepts such as quantum entanglement and quantum teleportation.[162] It also provides measures of quantum information, such as quantum entropy and quantum mutual information, which capture the unique features of quantum systems.[163] In this sense, Shannon's information theory continues to provide a foundation for quantum information theory as a foundation that information entropy is related to the second law of thermodynamics, which describes the natural tendency of an isolated system to degenerate into a more disordered state.[164]

2. The Philosophy of Information

Luciano Floridi's work suggests that the new concept of Shannon information expands the conceptual framework of social science, empowering the analysis and interpretation of the vast amounts of information generated in the digital age.[165] His work recognizes the inherent uncertainty and unpredictability within information. Social science can navigate the vast sea of data with greater discernment, distinguishing between noise and valuable insights.[166] Moreover, understanding the transformative potential of information entails not only its acquisition and dissemination, but also the responsible and ethical use in decision-making processes, policy formation, and social

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162. CHRIS BERNHARDT, QUANTUM COMPUTING FOR EVERYONE 68–69, 132–35 (2019).

163. MARK M. WILDE, FROM CLASSICAL TO QUANTUM SHANNON THEORY 21 (2019) ("The name quantum Shannon theory is fit to capture this area of study because we often use quantum versions of Shannon's ideas to prove some of the main theorems in quantum Shannon theory.").

164. Shannon's influence continues in the recent development of quantum computing, which makes use of quantum information theory. *See* MICHAEL A. NIELSEN & ISAAC L. CHUANG, QUANTUM COMPUTING AND QUANTUM INFORMATION 3–4 (2000). For a description of Shannon's contribution to quantum information theory, see GLEICK *supra* note 74, at 371–72. This new theory of information extends the concepts of Shannon information theory to the realm of quantum mechanics, exploring the behavior and manipulation of quantum systems as carriers of information. *Id.* Unlike classical bits, which can only represent 0 or 1, quantum bits or "qubits" can exist in a superposition of states, allowing for more complex information processing. *Id.* at 365.

165. *See* LUCIANO FLORIDI, THE ONLIFE MANIFESTO: BEING HUMAN IN A HYPERCONNECTED ERA 7 (2009) (noting that "online" is no longer separate from the day-to-day life of most people in developed countries. It is "onlife" and that one might use the phenomenological term to conclude that online is part of the lifeworld).

166. *Id.*

thought. The implications of Floridi's work extend into the realm of personal identity and social dynamics.[167] The proliferation of information through digital networks has given rise to new challenges, such as information overload, information manipulation, and privacy concerns.[168] Floridi's framework urges us to critically engage with these challenges, developing information literacy skills, critical thinking abilities, and ethical frameworks to navigate the complexities of the information age. Thus, Floridi invites us to reassess our epistemological landscapes and adapt our conceptual frameworks to embrace the complexities and opportunities presented by the digital era. As we navigate this information-rich landscape, it is imperative that we develop the necessary skills, ethical considerations, and critical perspectives to harness the transformative power of information in shaping a more informed, enlightened, and interconnected world.[169]

B. Complexity Science and Algorithmic Information

1. Complexity Science

With this understanding of information theory in hand, this section develops a description of complexity science. Complexity science is a burgeoning field that represents an interdisciplinary approach to studying the dynamic processes of variation and selection

167. *See id.* at 69, 97–98.

168. For a discussion of the widely-recognized impact of data science on social thought, *see, e.g.*, THE ETHICS OF ARTIFICIAL INTELLIGENCE (S. Matthew Liao ed., 2020).

169. The concept of information holds implications for the question of objectivity in social science. The implications of information science are similar to Weber's and Goodman's: while it repudiates the notion of a singular objective social world (thesis 1), and rejects a uniquely optimal theory, (thesis 2), information suggests the existence of objective social facts (thesis 1) alongside the potential for well-grounded theories (thesis 2). *See supra* notes 85–86 and accompanying text. It posits that the social world exhibits both material and subjective dimensions, with the convergence of theoretical beliefs (thesis 5) realizable through the internal mechanisms inherent to social science disciplines. *See supra* note 89 and accompanying text. Understood in this way, the concept of objectivity in the realm of social science pervades discussions, evoking profound inquiries into the existence of autonomous social facts and phenomena that can be investigated and comprehended through scientific methodologies. A theory's claim to represent an objective scientific analysis of social phenomena presupposes a solid grounding in empirical evidence and rigorous theoretical reasoning.

that govern complex systems.[170] Given the many different forms that complexity science takes across a variety of disciplines, it is not easy to provide a concise definition. One way to think about a complex system is as a collection of interconnected or interwoven parts. Understanding such systems requires investigating not only their individual components but also their emergent behavior as a whole.

Consider Parisi's example of a murmuration of starlings, mentioned above, where each bird follows a simple set of rules regarding the distance it should keep from its neighbors and the direction it should fly. Yet, from these simple behaviors, complex shapes and aerobatics arise as the birds interact with each other and their environment. Similarly, in her influential book, *Complexity, a Guided Tour,* Melanie Mitchell cites the observation of Nigel Franks, a biologist with expertise in ants, to illustrate the enigmatic feature of ant colonies as an example of complex systems.[171] Ants, despite very simple individual actions, exhibit very complex emergent group behaviors that contribute to the longevity of their species.[172] Complexity science studies these types of emergent phenomena in nature but importantly can be used to understand human social interactions.[173]

Applying this basic definition to a more everyday social structure lets us imagine observing the emergent behavior of a crowded New York City train station during a rainy rush hour. For example, imagine Grand Central Station during a rainy rush hour. Swarms of commuters rush about in what seems like mad chaos. Some form lines, others rush about, sidestepping each other. After a few minutes of observation, however, patterns can be seen. The behavior of the crowd emerges from thousands of individual choices, influenced by a number of factors. They are influenced by physical factors, such as the width of the path through the crowd or the slipperiness of the floor. They are influenced by established social norms, and by intentionally placed directive symbols. Despite the thousands of individuals navigating their destinations with little or no awareness of their collective behavior, group behaviors emerge from their activity.

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170. *See* BAR-YAM, *supra* note 33, at xi.

171. MITCHELL, *supra* note 29, at 3–4.

172. *Id.*

173. For an examination of complexity science's influence on social thought, see LITTLE, *supra* note 12.

This emergent order is constantly adapting and evolving based on new conditions. If a sudden thundershower hits, it will bring not only an influx of wet travelers, but with them new patterns of movement. The travelers now dodge the slick spots and puddles on the marble floor. A new crop of vendors appears, selling umbrellas and rain ponchos. If a child becomes separated from their parent, the surrounding crowd reacts to the sound of their cries, and a new behavioral pattern emerges. Contemporary complexity science studies the emergent behavior of complex systems from Parisi's example of a murmuration of starlings, to the complexity of ant colonies, to the movements of crowds in a busy train station. It holds immediate implications for social theory, since it highlights the importance of investigating both individual components and emergent behaviors of social groups as a whole, and offers insights into the dynamic processes of variation and selection that underlie complex systems in nature and human society.

2. Basic Concepts of Contemporary Social Systems Theories

Complexity science seeks to explain how large numbers of relatively simple entities organize themselves into a collective whole that creates patterns, uses information, and, in some cases, evolves and learns, without the benefit of any central controller.[174] Complexity science cuts across disciplinary boundaries and seeks to find common ground in dynamic patterns that are present as emergent behaviors in many areas. Examples include how individual members of the economy can produce complex but structured global markets; how consciousness emerges from nonconscious material substrates; and how the world wide web, consisting of individuals with little or no central oversight, creates a network containing large-scale properties that emerge from the behavior of the individuals. The study of complexity science provides insights into the fundamental processes that underlie complex systems, offering new ways to understand and address many of the most challenging issues facing society today.

174. *See* MITCHELL, *supra* note 29, at 12–13; BAR-YAM, *supra* note 33, at 1–2; LADYMAN & WIESNER *supra* note 22, at 12.

i. Self-Organization

Self-organization is a central concept in complexity science and seeks to explain the behavior of systems composed of many interacting parts. At its core, self-organization refers to the ability of such systems to spontaneously form patterns and structures without the need for external direction or control. These patterns can emerge from the interactions between individual agents, which may be as simple as molecules or as complex as human beings.[175] One of the key insights of complexity science is that self-organization is not simply the absence of external control, but a process that is actively driven by the behavior of the individual agents.[176] This newly detected order is characterized by its ability to adapt to changing conditions and its resilience in the face of perturbations or disruptions.[177] The study of self-organization has wide-ranging implications for a diverse array of fields. By understanding how self-organized systems operate, researchers can gain insights into the behavior of complex natural and social phenomena and develop new tools for modeling and predicting their behavior. Ultimately, this may lead to approaches for solving some of the most pressing challenges facing humanity today.

ii. Nonlinear Scaling

A second property of complex systems is nonlinear scaling: the notion that small changes can produce disproportionate results. In the early 1960s, Edward Lorenz was working on a numerical model of weather patterns.[178] His goal was to develop a mathematical model that could predict the weather for the next few days, but he quickly realized that even small changes in his initial conditions were leading to vastly different outcomes.[179] To understand why this was happening, Lorenz began closely studying the equations he was using to model the weather.[180] What he discovered was that the equations were highly nonlinear, meaning that small changes in one variable could have a

175. *See* MITCHELL, *supra* note 29, at 4–12.
176. *Id.* 12–13.
177. *Id.* at 13.
178. JAMES GLEICK, CHAOS, MAKING A NEW SCIENCE 11–31 (1987).
179. *Id.* at 11–16.
180. *Id.* at 16–17.

large impact on the outcome of the system.[181] He also found the equations were chaotic, which meant the system's behavior was highly sensitive to initial conditions.[182] This sensitivity to initial conditions caused his weather predictions to diverge so quickly.[183] Lorenz's discovery led to the realization that nonlinear scaling is present in weather systems.[184] He called this the butterfly effect, which comes from his famous example of a butterfly flapping its wings in Brazil and causing a tornado in Texas.[185] This means that small changes in the environment or in the behavior of one part of the system can have a large impact on the overall behavior of the system.[186] This sensitivity to initial conditions can make it difficult to predict the behavior of complex systems, as even small errors in our models or measurements can lead to vastly different outcomes.

3. Complex Systems and Algorithmic Information

A consequence of nonlinear scaling is made apparent when a complex system is interpreted through an information theory known as Kolmogorov complexity.[187] This is an approach to interpreting complex systems that was developed in computer science and information theory: it is a measure of the amount of information contained in a string of data.[188] The basic idea behind Kolmogorov complexity is that the amount of information in a string of data is equal to the length of the shortest possible algorithm that can generate that string.[189] In other

181. *Id.* at 23–25.
182. *Id.* at 20–23.
183. *Id.* at 22–23.
184. *Id.* at 25.
185. *Id.* at 22–23.
186. *See* LADYMAN & WIESNER, *supra,* note 22, at 99–101.
187. The concept is also known as algorithmic complexity, which was independently discovered by Gregory Chaitin. For a technical introduction, see Alexander Shen, *Algorithmic Information Theory*, *in* THE ROUTLEDGE HANDBOOK OF PHILOSOPHY OF INFORMATION 37–43 (Luciano Floridi ed., 2016); BAR-YAM, *supra* note 33, at 705–08; LADYMAN & WIESNER, *supra* note 22, at 110–115, app. at 139–40. *See also* GLEICK, *supra* note 74, at 333–38 (discussing Kolmogorov and his work in complexity). *See generally* ALEXANDER SHEN, VLADIMIR ANDREEVICH USPENSKIĬ, & NIKOLAI KONSTANTINOVICH VERESHCHAGIN, KOLMOGOROV COMPLEXITY AND ALGORITHMIC RANDOMNESS (2017) (textbook discussing algorithmic complexity and its applications).
188. *See* Shen, *supra* note 187, at 37.
189. *See id.*

words, if you have a string of data, the Kolmogorov complexity of that string is the length of the shortest computer program that could produce that string as output.[190] This concept is particularly powerful because it allows us to measure the complexity of a piece of information independent of any specific representation or encoding.[191] For example, consider the string of data "0101010101." If we represent this string using a binary encoding, it would take 10 bits to store.[192] But the Kolmogorov complexity of this string is only one bit, because we can generate it using a simple program that outputs "0" and "1" in an alternating pattern.[193]

Kolmogorov complexity is also useful for describing complex social systems. Specifically, it can be used to describe the complexity of the network structure and the behavior of individual agents within it.[194] This can help identify patterns in how agents interact, how information flows through the network, and how different structures can affect the overall performance of the network. For example, consider a social network like Facebook. Describing all the interactions and connections between its millions of users would require an enormous amount of information. Traditional economic models assume that individuals act rationally and make optimal decisions based on complete information. However, complexity science recognizes that individuals have limited information and are subject to biases and social influence. By using Kolmogorov complexity, researchers can instead describe the network in terms of a relatively simple set of rules and algorithms that define its structure and behavior. This method of description allows them to

190. For a technical introduction, see GLEICK, *supra* note 74, at 333–38. *See generally* MING LI & PAUL VITÁNYI, AN INTRODUCTION TO KOLMOGOROV COMPLEXITY AND ITS APPLICATIONS (3d ed. 2008) (textbook exploring algorithmic complexity).

191. GLEICK, *supra* note 74, at 337.

192. NEILS HENRIK GREGERSEN, FROM COMPLEXITY TO LIFE: ON THE EMERGENCE OF LIFE AND MEANING 22 (2003).

193. *See id.*; MITCHELL, *supra* note 29, at 98–99.

194. LADYMAN & WISENER, *supra* note 22, at 44 ("Combining the notions of computability and statistics one can express the complexity of a single object. This complexity is the length of the shortest binary programme from which the object can be effectively reconstructed. It is known as algorithmic complexity or Kolmorgorov complexity."). Examples of application of complexity science to social science can be found in anthropology. *See, e.g.*, DRIES DAEMS, SOCIAL COMPLEXITY AND COMPLEX SYSTEMS IN ARCHAEOLOGY (2021).

compress and abstract the complexity of the system, making it more manageable to study and analyze.

From the former descriptions, the usage of Kolmogorov complexity and Bayesian epistemology for information and complexity science appears to offer valuable resources for understanding and quantifying uncertainty and information in complex systems. Bayes's theorem provides a probabilistic framework for updating beliefs based on evidence, while Kolmogorov complexity offers a measure of the intrinsic complexity or information content of data. The combination of these ideas can provide insights into the interplay between probability, belief, and complexity, contributing to a deeper understanding of epistemology. In the contemporary period, where statistical modeling, machine learning, and other new techniques of analysis are increasingly used by policymakers to analyze an ever-growing sea of social data, the importance of the epistemological foundations of these methods grows with urgent implications.[195]

C. Complexity Science and Social Science

1. Complexity Science and the Social Sciences

The implications of complexity science to social science begin from the premise that the order of a society is neither static nor chaotic. It is an evolving, dynamic process that responds to stimuli, much like a living system.[196] This suggests an emerging view of the social world as a mix of assemblages, compounds, and aggregations. The social world is not like the natural world because its actors (human and non-human) arise from socially situated activities, concepts, thoughts, correlations, and other relational interactions.[197]

This is not to say that order does not exist in the social world. Patterns exist in social behavior that are regular and stable over long

195. *See* COLANDER & KUPERS, *supra* note 150; Noson S. Yanofsky, *Kolmogorov Complexity and Our Search for Meaning,* NAUTILUS (July 31, 2018), https://nautil.us/kolmogorov-complexity-and-our-search-for-meaning-237158/.

196. *See generally* GEOFFREY WEST, *The Simplicity, Unity, and Complexity of Life*, *in* SCALE: THE UNIVERSAL LAWS OF LIFE, GROWTH, AND DEATH IN ORGANISMS, CITIES, AND COMPANIES 79 (2018) (describing the significance of nonlinear scaling in biological and social systems).

197. LITTLE, *supra* note 12, at 5.

periods. Empirical methods have made (and can continue to make) considerable progress in describing, with mathematical rigor, the social relations that contribute to observed phenomena. As society becomes more connected through technology and globalization, social relationships have become increasingly complex and difficult to understand.

Complexity science offers a framework for analysis, allowing researchers to identify key patterns of behavior. By recognizing the interconnected nature of social phenomena, complexity science challenges traditional reductionist approaches that seek to break things down into their component parts. Instead, it emphasizes the importance of studying systems as a whole, taking into account the interactions between individual components. This perspective has led to a more holistic and interdisciplinary approach to research in the social sciences, which is better suited to addressing the complex challenges facing society today.[198]

Complexity science has far-reaching implications for understanding society as a whole. It suggests that a new genealogy of law is required to account for indirect and nonlinear causal inferences, self-organization, emergent behaviors, and nonlinearly coupled systems. Moreover, recent work in the philosophy of mathematics and science supports the view that a mathematical structuralism might be a useful presupposition for developing a genealogy of law that views social structures as complex systems.[199] A complexity science of law must

198. The complexity perspective on policy is suggested here:

> The central policy choice in a complexity frame is not—either the market or the government. The goal of policy in the complexity frame is not to choose one or the other. Instead, policy is seen as affecting a complex evolving system that cannot be controlled. But while it cannot be controlled, it can be influenced, and policy makers have to continually think how to work with evolutionary pressures, and try to guide those pressures toward desirable ends.

COLANDER & KUPERS, *supra* note 150, at 8.

199. STEWART SHAPIRO, *Structuralism*, *in* THINKING ABOUT MATHEMATICS: THE PHILOSOPHY OF MATHEMATICS 257 (2000).

also acknowledge the acceptance of systems research in the social sciences.[200]

2. Features of Complex Social Systems

For the purposes of empirical CRT (eCRT), three features are particularly relevant: structural realism, social ontology and assemblage theory, and complexity and causality in complex systems.

i. Structural Realism and Theory Replacement

Structural realism is the view that while we cannot know about the intrinsic properties of things in the world, we can have knowledge of structural properties.[201] The history of this belief is long and varied. Among philosophers in the West, it has ties to Anaximander, Leibniz, and twentieth century process philosophers like Alfred North Whitehead and Gilles Deleuze.[202] One of the main advantages of structural realism is that it provides a framework for scientific inquiry that is independent of specific metaphysical theories, since the structures of the world can be known and this knowledge is not tied to any specific philosophical method.[203] This means that even if a theory is later found to be

200. For an introduction to complexity in law, see Jamie Murray, Thomas E. Webb, & Steven Wheatly, *Encountering Law's Complexity*, *in* COMPLEXITY THEORY AND LAW: MAPPING AN EMERGENT JURISPRUDENCE 3 (Jamie Murray, Thomas E. Webb, & Steven Wheatly eds., 2019) (arguing that complexity in law should be read through Cilliers's work); LAW AS DATA: COMPUTATION, TEXT, AND THE FUTURE OF LEGAL ANALYSIS (Michael A. Livermore & Daniel N. Rockmore eds., 2019) [hereinafter LAW AS DATA]. *See also* Ronald Allen, *Taming Complexity: Rationality, the Law of Evidence and the Nature of the Legal System*, 12 L. PROBABILITY & RISK 112 (2013) (arguing, against Dworkin, that solutions to legal problems within the legal system as a whole, as compared to any particular node within the legal system, are arrived at through a process of inference to the best explanation that occurs within a highly interconnected set of nodes similar to a neural or social network).

201. James Ladyman, *Structural Realism*, STAN. ENCYC. PHILOSOPHY, https://plato.stanford.edu/entries/structural-realism/ (May 18, 2023).

202. *See generally* STEVEN SHAVIRO, WITHOUT CRITERIA: KANT, WHITEHEAD, DELEUZE, AND AESTHETICS (2009).

203. James Ladyman and Don Ross argue that philosophy has often sought to restrict science in favor of conventional "folk" beliefs about structure and composition. JAMES LADYMAN, DON ROSS, DAVID SPURRIET, & JOHN COLLIER, EVERYTHING MUST GO: METAPHYSICS NATURALIZED 67 (2007). However, folk knowledge does not offer special insights into metaphysical truths. *Id.* at 10–15. Some endorse unverifiable statements through metaphysical containment, but this view contradicts contemporary

incorrect, the knowledge of the structures it shares with other theories would remain valid.[204] James Ladyman, one of the leading advocates for structural realism, argues that our knowledge of the world is always limited and that we can never have a complete understanding of it.[205] Structural realism acknowledges this limitation and proposes that our understanding of the world is always provisional and subject to revision. This means that even if we cannot know the intrinsic properties of the world, we can still gain a valuable understanding of its structures.[206] Ladyman, however, argues that some patterns of relations are reducible, but not all. And, critically, these non-reducible patterns also contribute to the structure of the world. He suggests that a more comprehensive approach to structural realism is needed, one that takes into account the full range of structural patterns that exist in the world.[207] Ladyman argues that it is important to ground philosophical theories in empirical evidence, and that a purely abstract approach risks losing touch with the realities of scientific practice.[208]

Of particular importance to eCRT is the realism of Gilles Deleuze, particularly as it has been interpreted and extended by Manuel DeLanda, who is a contemporary expositor of the philosophy of Deleuze. In Deleuze's seminal work, *Difference and Repetition*, he argues against what he takes to be the bias of European metaphysics to focus on similarities between objects. Difference, he argues, rather than sameness, should be the focus for metaphysics.[209] DeLanda extends

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science. *Id.* Despite challenges to metaphysics' viability, it persists as a successful field of knowledge. Let's reconsider the relationship between science and metaphysics for a more profound understanding of reality.

204. *See id.* at 67.

205. *See id.*

206. Steven French & James Ladyman, *Remodeling Structural Realism: Quantum Physics and the Metaphysics of Structure*, 136 SYNTHESE 33–34 (2003).

207. LADYMAN, ROSS, SPURRIET, & COLLIER, *supra* note 203, at 4.

208. *See, e.g.*, *id.* at 67.

209. GILLES DELEUZE, DIFFERENCE AND REPETITION (Paul Patton trans., 1994). For an introduction to Deleuze, see CLAIRE COLEBROOK, GILLES DELEUZE (2002). For a reading guide, see HENRY SOMERS-HALL, DELEUZE'S DIFFERENCE AND REPETITION (2013). Somers-Hall explains,

> . . . I take Deleuze to be giving us an account of the nature of the world, broadly construed. What makes his project appear almost unrecognizable when compared with traditional metaphysical approaches is that he is attempting to provide a metaphysics of difference. As we shall see, his claim is that when we take identity as

Deleuze by reference to a "flat" ontology.[210] According to DeLanda, a "flat" ontology recognizes that there is no inherent hierarchy or pre-established order in the world.[211] He means that social scientists should avoid thinking of the multiple levels of social ontology as hierarchical. DeLanda argues that traditionally, philosophical and social theories have often emphasized hierarchical structures or binary distinctions, such as mind/matter, culture/nature, subject/object, and so on. DeLanda argues for a "flat" ontology that challenges this hierarchical thinking and proposes a more horizontal or egalitarian understanding of reality.[212] Instead of a hierarchy, DeLanda acknowledges that entities at different scales and levels of complexity, from subatomic particles to social institutions, coexist and interact on an equal ontological footing. This means that everything that exists is an object without a privileged ontological status or necessary dominance over others. A flat ontology allows us to better understand the complexity of the social world and the interconnections between different entities. It enables us to analyze how entities emerge, interact, and transform through processes of self-organization and self-constitution.

> prior to difference, exemplified in the belief in judgment as the basis for philosophical enquiry, we are constrained to make a number of claims about the nature of the world and the nature of knowledge. These claims together form the traditional image metaphysics. In *Difference and Repetition*, Deleuze renounces the priority of identity, which leads to a very different kind of metaphysical inquiry.

Id. at 1.

210. DeLanda explains,

> [W]hile an ontology based on relations between general types and particular instances is *hierarchical*, each level representing a different ontological category (organism, species, genera), an approach in terms of interacting parts and emergent wholes leads to a *flat ontology*, one made exclusively of unique, singular individuals, differing in spatio-temporal scale but not in ontological status.

MANUEL DELANDA, INTENSIVE SCIENCE & VIRTUAL PHILOSOPHY 51 (2002).

211. *Id.*

212. DeLanda stresses that instance of existence is constructed of individual entities. *Id.* at 34. Even species and genera are compositions of individuals. *See id.* This sweeping assertion challenges prevailing paradigms and beckons us to a nuanced contemplation of the universe—a realm woven intricately from the warp and weft of singular beings. DeLanda's intellectual vision encourages us to apprehend the world anew, liberated from the constraints of conventional essentialist ontological frameworks.

ii. Social Ontology and Assemblage Theory

One of the key contributions that complexity science can make to the field of social ontology is the importance of studying processes and interactions rather than just static outcomes or structures. While social reality is constructed from the actions and beliefs of individuals, social structures and institutions have their own ontological significance. Just as individual birds have agency, so too does the flock as a whole. Individual birds shape the flock, but the flock in turn embodies the collective actions of the individuals. In a human society, this means that individual actions, beliefs, meaning, etc., shape and are shaped by society in ways that can be subtle and difficult or impossible to predict. This suggests that social systems are inherently unpredictable and subject to nonlinear and sometimes chaotic dynamics, which can help explain unexpected or counterintuitive social phenomena.

DeLanda revises Deleuze's concept of the assemblage.[213] For DeLanda, an assemblage is a temporary and heterogeneous gathering of diverse elements, both human and non-human, that come together to form a complex system or entity.[214] For example, social systems and natural systems can couple, indirectly affecting one another. The weather is a system that indirectly influences the commodities markets. When it is cold in the orange groves, orange juice futures are at a premium. The elements in an assemblage can include individuals, institutions, technologies, discourses, physical objects, and more. As complex systems, assemblages are characterized by their emergent properties, meaning that the whole assemblage possesses properties and capacities that are not reducible to the individual elements alone.[215] DeLanda emphasizes that assemblages are not static or hierarchical formations. Instead, they are characterized by complex relationships, interactions, and flows of energy and information between their constituent elements.[216] Assemblages are also embedded within broader assemblages, forming nested and interconnected systems. Analyzing assemblages yields insights into how social, cultural, and material

213. MANUEL DELANDA, ASSEMBLAGE THEORY 1 (2016). For an introduction to assemblage theory, see IAN BUCHANAN, ASSEMBLAGE THEORY AND METHOD (2021).

214. DELANDA, *supra* note 213, at 1.

215. *Id.* at 1–2.

216. *Id.*

entities emerge, persist, and transform over time. DeLanda's analysis of assemblages responds to insights about how technology is altering basic understandings of the nature of epistemology and social ontology. DeLanda's concept of assemblage provides a framework for studying the complex and contingent nature of social and material configurations, emphasizing their emergent properties and the interplay between diverse elements within dynamic systems.

Since complexity science understands that complex systems often exhibit nonlinear dynamics, where small changes can lead to significant and unpredictable effects, random information sequences can have tremendous impact on emergent behavior. This feature of nonlinearity is relevant to the insights gained from algorithmic (Kolmogorov) information theory. It suggests that much of the information in a social system cannot be reduced to rules, since it is the incompressible information of context that expresses random events in the past. The evolution of a social system occurs at many levels; the individual, the social group, the culture as a whole have evolutionary histories that reflect a multitude of random events.

Manuel DeLanda has interpreted the significance of this aspect of complex systems by drawing inspiration from Deleuzian assemblage theory.[217] This theoretical lens underscores the critical role of contextual factors in comprehending the complex tapestry of race within society. Manuel DeLanda has expanded the concept of context in complex systems by drawing on the works of Gilles Deleuze and Félix Guattari, particularly their concept of the "assemblage" in their book, *A Thousand Plateaus*.[218] For DeLanda, the focus is on the relations and interactions between various interlocking systems rather than on the elements themselves. DeLanda views the world as composed of heterogeneous entities, such as humans, objects, institutions, natural forces, and technological systems which come together in specific configurations to form assemblages.[219] These assemblages are not fixed or stable but are constantly changing and evolving. Assemblages are temporary configurations of entities and processes that emerge from the

217. *See id.* at 1.

218. *See id.*; GILLES DELEUZE & FELIX GUATTARI, A THOUSAND PLATEAUS: CAPITALISM AND SCHIZOPHRENIA (Brian Massumi trans., 2011).

219. DELANDA, *supra* note 213, at 1.

interactions between different elements.[220] A key aspect of assemblage theory is its emphasis on the materiality and agency of entities, including material entities, within an assemblage.[221] Agency is not solely attributed to humans but also extends to non-human entities, such as objects or natural forces.[222]

For example, racial belief systems, far from existing in isolation, are enmeshed within the broader fabric of social, economic, and political contexts. It is within this rich contextual milieu that the behavior and manifestations of racial beliefs unfold, their trajectories intricately intertwined with the ebbs and flows of the sociopolitical landscape, economic policies, and legal frameworks. Through an interdisciplinary investigation, eCRT may gain a deeper appreciation for the multifaceted concealed systemic dynamics of race. It is through this holistic lens that we untangle the intricate threads that shape the persistence of racial disparities, empowering ourselves with a comprehensive understanding of the intricacies that underlie the pursuit of racial equity. By unraveling the complex dynamics at play, it is possible to pave the way for evidence-based strategies aimed at fostering a more just and inclusive society.

iii. Complexity and Causality in Social Systems

The study of causation in complex social systems represents a frontier of knowledge that continues to evolve and challenge researchers.[223] Social systems, comprising networks of individuals and institutions, exhibit inherent complexity arising from the nonlinear interactions between various elements. The concept of nonlinearity as is described above is a feature of complex systems where a multitude of agents interact in ways that produce emergent behaviors that are unpredictable, like a flock of starlings.[224] Like all complex systems, social systems are characterized by self-organization and nonlinear scaling that leads to emergent behaviors that cannot be easily deduced from the properties of individual components. Understanding causation

220. *Id.* at 10–14.
221. *Id.* at 20.
222. *Id.*
223. BYRNE & CALLAGHAN, *supra* note 39, at 141.
224. *See* LADYMAN & WIESNER, *supra* note 22, at 10.

within social systems demands a departure from reductionist thinking and the adoption of a holistic perspective that embraces the nonlinear nature of human interactions. By embracing the intricacies of human interactions, network science, multilevel analysis, and contextual factors, researchers can unlock deeper insights into the causal dynamics shaping social phenomena. The implications of this research extend beyond academia, offering the potential to shape evidence-based policies and interventions that navigate the complexities of our interconnected world.[225]

Causal inference within social systems faces significant challenges due to the interplay of multiple factors, the presence of hidden variables, and the difficulty of conducting controlled experiments. While randomized controlled trials ("RCTs") provide a gold standard for causal analysis, their applicability in social systems is often limited.[226] Consequently, researchers have turned to alternative methodologies—such as observational studies, natural experiments, and computational modeling—to explore causation in social systems. These approaches rely on pattern detection, statistical techniques, and simulations to identify causal relationships amidst the complexity of social phenomena.

Since the hallmark of complexity in social systems is the presence of emergent properties that transcend the actions of individual components, causation in social systems is often difficult or impossible to precisely model. The presence of feedback loops, for example, can give rise to phenomena such as information cascades, social contagion, and tipping points, amplifying the impact of initial causes and leading to dramatic shifts in social dynamics.[227] Nonlinear scaling leads to systems that involve non-compressible information, which cannot be modeled through algorithmic reduction. Understanding and harnessing these properties is crucial for predicting and shaping the behavior of social systems. Moreover, social systems operate within specific contexts, influenced by cultural, historical, and environmental factors. Since causation within social systems often occurs at multiple levels, where

225. For some suggestion about why complexity matters to policy, see COLANDER & KUPERS, *supra* note 150, at 273–75.

226. BYRNE & CALLAGHAN, *supra* note 39, at 176.

227. *See* COLANDER & KUPERS, *supra* note 150, at 214–36.

individual-level actions interact with higher-level structures and institutions, analysis of social phenomena must also account for emergent behavior at multiple levels of organization. Complex systems are characterized by multilevel causation, and analyses of them must consider how macro-level factors shape individual behavior and how individual actions, in turn, shape the macro-level outcomes. Accounting for contextual factors and multilevel causation provides a more comprehensive understanding of the complexities of social systems and the interdependencies between micro and macro levels of analysis.[228]

Understanding complex causation in social systems holds profound implications for policymaking and intervention strategies.[229] By deciphering the causal mechanisms underlying societal issues, policymakers can develop iterative interventions that address assemblages of causes rather than symptoms. Complex causality analysis enables the identification of leverage points, where small interventions can have cascading effects, resulting in significant social change. Evidence-based policies rooted in a deep understanding of complexity science and causation offer the potential to create more resilient, equitable, and sustainable social systems. Critically, however, the study of complexity and causation in social systems extends beyond theoretical inquiries. It necessitates a close collaboration between researchers and practitioners, fostering interdisciplinary dialogues that bridge the gap between academia and the real world. Policy decisions and interventions that aim to address societal challenges must be grounded in a nuanced understanding of the causal mechanisms at play in social systems. By embracing complexity and causality, policymakers can adopt a more holistic approach, designing interventions that account for the interconnectedness, feedback loops, and emergent properties inherent in social systems.

228. For an introduction to causality in complex systems, see Judea Pearl, *An Introduction to Causal Inference*, 6 INT'L. J. BIOSTATISTICS (2010). *See generally* JUDEA PEARL & DANA MACKENZIE, THE BOOK OF WHY: THE NEW SCIENCE OF CAUSE AND EFFECT (2018).

229. *See* COLANDER & KUPERS, *supra* note 150, at 273–75.

III. APPLYING COMPLEXITY SCIENCE TO ECRT

A. Bridging the Epistemic Gap through Complexity Science in eCRT

1. Complexity Science and the Epistemology of Social Science

As is described above, the epistemic gap between CRT and empiricism exists because of the vastly different values of the two approaches. CRT recognizes the multifaceted nature of race and racism. However, its traditional methodologies often focus on narratives of individual experiences and overt forms of discrimination. The focus on subjective and qualified epistemological value complicates the exploration of the vast quantities of data and the application of the hidden order discovered in complex systems. Nonetheless, there are systemic and emergent aspects of racial dynamics that could be usefully explored by eCRT. By integrating complexity science, eCRT scholars can address these limitations and capture the intricate interplay between individuals, institutions, and social structures. Since complexity science highlights the significance of nonlinear dynamics, where small changes in initial conditions can yield significant and unexpected effects, it can be crucial in understanding the perpetuation of racial inequalities and the role of information structures in perpetuating racial hierarchy. By examining how racial biases and discriminatory practices interact within social systems, complexity science can shed light on the self-reinforcing nature of racial hierarchies, enabling more effective interventions.

The work of Paul Cilliers, a South African philosopher and complexity thinker, is useful to resolving the tension between empiricism and critical studies, since he identified some significant connection between complexity science and postmodernism.[230] Cilliers argues that complexity science offers valuable insights into the behavior of collective social phenomena that extend beyond the actions and intentions of individuals.[231] Although Cilliers's work did not directly

230. *See* CILLIERS, *supra* note 39. For a discussion of his thought, see BYRNE & CALLAGHAN, *supra* note 39, at 28–32.

231. Cilliers argues that the term "relational properties" might be better than "emergent." CILLIERS, *supra* note 39, at 143 n.2; *see* BYRNE & CALLAGHAN, *supra* note 39, at 85.

address epistemology in the social sciences, his ideas on complexity science have implications for how we understand knowledge generation, interpretation, and validation in complex social systems. By emphasizing the interconnectedness, emergence, and unpredictability of complex systems, Cilliers challenges traditional notions of objective knowledge and linear causality.[232] Instead, he advocates for a more reflexive and context-dependent understanding of knowledge and encourages scholars in the social sciences to embrace complexity in their epistemological frameworks.[233]

Cillers argues that in traditional empirical approaches, the focus is often on explicit and intentional individual acts of discrimination, overlooking subtler and more systemic dynamics.[234] Yet, it is these dynamics that contribute to racial inequalities. Complexity science, on the other hand, emphasizes the interconnectedness of various actors and factors within social systems, acknowledging that the outcomes of these interactions are not solely determined by individual intentions or actions.[235] By embracing complexity science, eCRT gains a deeper understanding of the hidden complexities that sustain and reproduce racial inequalities. It illuminates how seemingly innocuous actions, policies, or norms can have unintended consequences that perpetuate racial disparities. For instance, a facially neutral housing policy can have a cascading discriminatory effect, leading to residential

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232. Cilliers explains,

> In this study we have so far concerned ourselves with the development of an understanding of complexity at a fairly technical level. In the process we have continuously opposed two approaches—the formal, rule-based, representational one and the distributed, self-organising, connectionist one. The general conclusion has been that the rule-based approach is not sensitive enough to the general characteristics of complex systems. It has been argued that connectionist models fare somewhat better since they are implicitly sensitive to the relational character of complex systems, perhaps as a result of the fact that they are based on the best example of a complex system we know—the brain. Even though their capabilities may at present be nowhere near those of the mammalian brain, they at least incorporate some of the general characteristics of complex systems.

CILLIERS, *supra* note 39, at 112.

233. BYRNE & CALLAGHAN, *supra* note 39, at 39.

234. *Id.* at 23–25.

235. *Id.* at 29–32.

segregation and unequal access to resources and opportunities for different racial groups.[236] Furthermore, complexity science helps us recognize the role of feedback loops in perpetuating racial inequalities. Feedback loops are self-reinforcing cycles in which initial advantages or disadvantages for certain racial groups can amplify over time, creating and maintaining systemic disparities.[237] These feedback loops can operate through various mechanisms, such as biased decision-making processes, differential access to educational opportunities, or discriminatory practices within institutions.

If eCRT were informed by complexity science, it would systematically analyze and uncover these hidden complexities and feedback loops. It can identify how seemingly unrelated factors and interactions contribute to racial disparities and how they are sustained over time. By examining the interplay between individual actions, social structures, cultural norms, and historical legacies, researchers can trace the pathways through which racial inequalities are reproduced and perpetuated. This deeper understanding gained from complexity science enables empirical critical race theory to propose more effective strategies for dismantling racial inequalities. It highlights the need for comprehensive interventions that target not only individual acts of discrimination but also the underlying systemic structures and processes that contribute to racial disparities. By addressing the emergent and systemic aspects of racial dynamics, empirical critical race theory can advocate for transformative change that disrupts the feedback loops, challenges institutional biases, and fosters equitable opportunities for all individuals, regardless of their racial background. Two critical factors for CRT are the existence of multiple levels of social ontology and the sensitivity to initial conditions due to nonlinear scaling.

i. Multiple Ontological Levels

The existence of multiple levels of social ontology is a critical concept in complexity science of great significance for social science. The concept refers to the reality that social groups operate at varying

236. *See* discussion of the Schelling Segregation Model, *infra* notes 293–303 and accompanying text.

237. *Feedback Loop*, CAMBRIDGE DICTIONARY, https://dictionary.cambridge.org/us/dictionary/english/feedback-loop.

levels of complexity. Recall Parisi's starlings. The individual birds that comprise a flock must be considered in any description of its behavior. But, the behaviors of individual birds do not easily predict the behavior of the flock. The behavior emerges from the aggregate individual actions, but in ways that cannot be determined through a reductive, nomological analysis. Probabilistic analysis can yield only likely behavior and in generalized terms. This suggests that the flock as whole must be considered as having a social ontological status.

This generalized statement of social ontology must be modified for contemporary societies that are participants in the global information revolution, since technology plays a role, too, in determining behavior.[238] This is truer today than in the past since, as Floridi has noted, most people in developed countries spend more time online than not. As Floridi noted: they have an "onlife."[239] The data exhaust that they leave behind from their onlife activities is used to identify and categorize them. They become bundles of commercially exploitable traits, habits, and preferences in the eyes of the online economy. Since the algorithms are more efficient when they create desire than when attempting to predict it, they seek to generate desire—they are the engines of desire.[240] Individual behaviors and motives will not adequately explain the behavior of groups, and the motives and behaviors of small groups will not explain the behavior of large groups. Similarly, CRT acknowledges that racism operates at multiple levels, from individual attitudes to institutional structures to national cultures. Complexity science can help explain how racism emerges and evolves through interactions among various social actors, institutions, and cultural norms.

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238. Brian Epstein, *Social Ontology*, STAN ENCYC. PHILOSOPHY (Mar. 21, 2018), https://plato.stanford.edu/archives/win2023/entries/social-ontology/. For an introduction to social ontology, see JOSHUA GLASGOW, SALLY HASLANGER, CHIKE JEFFERS, & QUAYSHAWN SPENCER, WHAT IS RACE? FOUR PHILOSOPHICAL VIEWS (2019); ANTHONY APPIAH, MY FATHER'S HOUSE: AFRICA IN THE PHILOSOPHY OF CULTURE (1992); CHARLOTTE WITT, THE METAPHYSICS OF GENDER (2011).

239. *See generally* FLORIDI, *supra* note 165.

240. *See, e.g.*, Matt Ritchtell, *Is Social Media Addictive? Here's What the Science Says*, N.Y. TIMES, (Oct. 25, 2023), https://www.nytimes.com/2023/10/25/health/social-media-addiction.html (explaining the addictive nature of social media algorithms).

ii. Sensitivity to Initial Conditions.

Cilliers recognizes nonlinearity and also underscores the sensitivity of complex systems, including language, to changing conditions.[241] Even slight variations can lead to significantly different outcomes.[242] Recall that nonlinear scaling means that complex systems will generate information and processes that cannot be reduced to a rule or algorithm. In the realm of critical race theory, this concept emphasizes the importance of contextual factors, such as historical legacies, in shaping racial dynamics. Complexity science permits us to more properly attribute the impact of seemingly subtle historical influences. These influences are often excluded from consideration in more traditional social sciences. For example, in neoclassical economic theory, the significance of the history of persons in a market has only recently been recognized in the field of behavioral economics.[243] For the complexity thinker in economics, price theory attempts to reduce market forces to a set of rules that compresses the surplus of information beyond its limits.

Similarly, by considering the historical context and recognizing the sensitivity of racial systems to initial conditions, empirical critical race theory can better explain the persistence of racial disparities and inform strategies for transformative change. Since historical legacies play a pivotal role in shaping racial dynamics, the impact of past

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241. Cilliers explains,

> A living language is in a state far from equilibrium. It changes, it is in contact with other languages, it is abused and transformed. This does not mean that meaning is a random or arbitrary process. It means that meaning is a local phenomenon, valid in a certain frame of time and space. Since every language also has a history—a history co-responsible for the meaning of terms—meaning is more stable than one would think, even within the context of a model that values flux and proliferation. Words bear with them the traces of previous meanings that cannot be discarded at will. Above all, language is a system in which individual words do not have significance of their own. Meaning is only generated when individual words are caught in the play of the system.

CILLIERS, *supra* note 39, at 124.

242. *Id.* at 4.

243. The theory of behavioral economics is described in Derek D. Reed, Christopher R. Niileksela, & Brent A. Kaplan, *Behavioral Economics*, 6 BEHAV. ANALYSIS PRAC. 34 (2013).

injustices, such as slavery, colonization, and segregation, reverberate through time, leaving lasting imprints on society. These historical legacies act as initial conditions that have influenced the development of racial systems. Complexity science emphasizes that the path-dependent nature of complex systems makes it difficult to disentangle the present from its historical roots. Therefore, any comprehensive analysis of racial disparities must consider the historical context that continues to shape current realities.

2. The Example of Habeas Viscus

An example of applying complexity science, as DeLanda describes, to race studies can be found in the thought-provoking book, *Habeas Viscus*, by Alexander G. Weheliye.[244] This study builds on Deleuze's concept of assemblage by introducing the concept of "racializing assemblages."[245] Weheliye proposes that race operates as a complex web of sociopolitical processes that classify individuals into distinct categories: those considered fully human, those regarded as not-quite-human, and those relegated to nonhuman status.[246] Although this classification is not inherently biological, it often relies on the embodiment of political hierarchies within human flesh.[247] To construct his argument, Weheliye draws heavily upon the groundbreaking work of Black feminist scholars Hortense Spillers[248] and Sylvia Wynter.[249] Spillers and Wynter challenge and disrupt the prevailing notion that white, Western men are the epitome of humanity, positioning Black studies as a vital enterprise in this intellectual endeavor.[250]

Significantly, Weheliye argues that the predominant works by Giorgio Agamben and Michel Foucault fail to adequately account for

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244. ALEXANDER G. WEHELIYE, HABEAS VISCUS: RACIALIZING ASSEMBLAGES, BIOPOLITICS, AND BLACK FEMINIST THEORIES OF THE HUMAN (2014).

245. *Is.* at 6.

246. *Id.* at 3.

247. *Id.* at 5.

248. *See* Hortense J. Spillers, *Member Directory*, AM. ACAD. ARTS & SCIS., https://www.amacad.org/person/hortense-j-spillers (Feb., 2024); WEHELIYE, s*upra* at 244, at 2.

249. SYLVIA WYNTER, ON BEING HUMAN AS PRAXIS (Katherine McKittrick ed., 2015); WEHELIYE, *supra* note 244, at 4–5.

250. WEHELIYE, *supra* note 244, at 25–32.

the profound impact of race in shaping notions of the human.[251] Weheliye highlights the significance of black feminist theories on modern humanity.[252] He posits that these theories provide crucial correctives to the dominant social discourse by underscoring the conceptual and political weight of race in the construction of the human.[253] Here, the synergy between assemblage theory and complexity science becomes apparent. Assemblage theory, with its emphasis on the interconnectedness and dynamic relationships among various elements, aligns with the narratives of intricate complexities inherent in the processes of racialization. Complexity science, on the other hand, provides an empirical framework for understanding the nonlinear and emergent properties of systems, allowing one to appreciate the intricate interplay of factors that shape our notions of the human. Ultimately, *Habeas Viscus* serves as an example of what eCRT could be. It is a compelling call to action, emphasizing the urgent need to incorporate the insights of Black studies and Black feminism into the core foundations of the study of modern humanity. By centering these perspectives, we can gain a more comprehensive understanding of how race operates within our sociopolitical systems and challenge the prevailing assumptions that have long perpetuated racial hierarchies.

To summarize, the integration of complexity science into eCRT holds great promise for advancing our comprehension of racial dynamics and bridging existing gaps in knowledge. This

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251. *Id.* at 29–30. In the author's judgment, while genealogical theories were part of the projects of Fredrich Nietzsche, Michel Foucault, and Georgio Agamben, complexity theory raises several novel issues. First, since complexity theory views evolution as the product of nonlinearly scalable forces, a new genealogy must allow for causal inferences that are multiple and Bayesian. It must consider features such as self-organization, emergent behaviors, and Assemblage. Second, the realism of social ontology might be a fruitful presupposition for developing a genealogy that views social structures as including complex systems open to mathematical investigation. And third, a complexity theory of law must acknowledge that systems research in the social sciences has become widely accepted. The dimensions of a systems theory approach to social theory is suggested by Byrne and Callaghan, who look to Herbert Spencer, Talcott Parsons, and Niklas Luhmann for the outline of such an approach. Critically, they adopt a non-biologically deterministic view, which considers social systems as distinct from natural sciences and develop independently alongside them. This commitment is necessary to adopt a "complexity-framed explanation of continuity and change and the significant evolutionary dimensions of historical materialism . . . ." BYRNE & CALLAGHAN, *supra* note 39, at 88.

252. WEHELIYE, *supra* note 244, at 29–30.

253. *Id.* at 5–6.

interdisciplinary fusion enables a deeper exploration of the intricate and nonlinear nature of social systems, shedding light on the emergent properties, sensitivity to initial conditions, and interconnectedness inherent in the study of race and racism. Complexity science challenges reductionist approaches, urging us to move beyond simplistic causality and embrace the complex web of factors that shape racial systems. By recognizing the sensitivity of these systems to initial conditions, we gain a deeper appreciation for the historical legacies and contextual factors that contribute to the persistence of racial disparities. Enriched by complexity science, eCRT could empower scholars to unravel the underlying mechanisms that sustain racial inequalities. It provides a framework to examine the interplay between historical legacies and contextual factors, elucidating the complex dynamics that perpetuate unequal power structures. This empirical approach offers valuable insights, identifying strategic leverage points for transformative change that can address the deep-seated systemic roots of racial inequities. This integration goes beyond simplistic explanations and linear causal chains, embracing the intricate interdependencies and feedback loops that characterize racial systems. By considering the nonlinear and emergent properties of social systems, eCRT gains a more comprehensive understanding of the complex dynamics at play. Ultimately, the integration of complexity science into eCRT propels us towards a future that strives for justice and equity. By bridging gaps in knowledge and expanding our understanding, we pave the way for evidence-based strategies and policies that foster a society committed to dismantling racial hierarchies. This interdisciplinary approach offers the potential for transformative change, paving the path to a more inclusive and equitable future for all.

The next section describes a method known as agent-based modeling ("ABM") for applying complex systems theories to social science. ABM is widely used in social science to describe the emergent behavior of social groups over extended periods of time. It has become an important research method in many fields.

B. Utilizing Agent-Based Modeling of Complex Systems

1. Agent-Based Modeling and Complexity Science

One of the most important tools for social science that has resulted from the application of complexity science is agent-based modeling.[254] ABM is a computational research approach that aims to simulate and analyze artificial societies as complex systems by modeling the behaviors and interactions of autonomous agents.[255] In ABM, agents represent individual entities within the system, such as individuals, groups, organizations, or even abstract concepts, each possessing their own set of attributes, rules, and decision-making capabilities.[256] These agents are capable of perceiving their environment, making autonomous choices based on their internal rules, and interacting with other agents within the system.[257] By simulating the interactions among a large number of agents over time, ABM allows researchers to study the emergence of collective behavior and the dynamics of complex systems.[258] The simulation typically proceeds in discrete time steps, where agents update their state and make decisions based on their internal rules and the information available to them.[259] The interactions among agents can include direct communication, cooperation, competition, or influence, leading to the emergence of patterns, behaviors, and outcomes at the macro-level that may not be predictable from the properties and actions of individual agents alone.[260]

The process of developing an agent-based model involves several steps.[261] First, researchers define the agents and their

254. For an accessible introduction to agent-based modeling, see IZA ROMANOWSKA, COLIN D. WREN, & STEFANI A. CRABTREE, AGENT-BASED MODELING FOR ARCHAEOLOGY: SIMULATING THE COMPLEXITIES OF SOCIETY 3–15 (2021). *See also* PAUL E. SMALDINO, MODELING SOCIAL BEHAVIOR (2023).

255. ROMANOWSKA, WREN, & CRABTREE, *supra* note 254, at 6–10, 32–35.

256. *See* JOSHUA M. EPSTEIN & ROBERT AXTELL, GROWING ARTIFICIAL SOCIETIES: SOCIAL SCIENCE FROM THE BOTTOM UP 1–20 (1996).

257. ROMANOWSKA, WREN, & CRABTREE, *supra* note 254, at 6–10.

258. *Id.*

259. For an example of ABM in a time series, see EPSTEIN & AXTELL, *supra* note 256, at 54–93.

260. ROMANOWSKA, WREN, & CRABTREE, *supra* note 254, at 6–10.

261. Detailed guides to the ABM process can be found in ROMANOWSKA, WREN, & CRABTREE, s*upra* note 254, at 6–10, 32–35; EPSTEIN & AXTELL, *supra* note 256, at 4–5; and SMALDINO, *supra* note 254, at 17–20.

characteristics, such as their attributes, rules, and decision-making processes.[262] Next, the researchers specify the environment in which the agents operate, including its spatial or social structure, resource distribution, and other relevant factors.[263] Researchers also determine the rules governing the interactions among agents, which may involve explicit communication, social norms, or adaptive learning processes.[264] Finally, researchers run simulations by allowing the agents to interact and observe the emergent patterns and dynamics that arise from the interactions.[265]

ABM offers several advantages for studying complex systems. It should contribute to studying race dynamics.[266] It provides a flexible and intuitive approach to capture the intricacies of social phenomena, enabling researchers to model and analyze systems that exhibit nonlinear behavior, feedback loops, and emergence.[267] ABM allows for the integration of diverse factors, such as individual agency, social context, historical contingencies, and complex causal mechanisms, providing a comprehensive understanding of how these elements interact to shape the system's behavior.[268] Moreover, ABM facilitates the exploration of counterfactuals ("what-if" hypothetical scenarios) and the testing of interventions or policies within the simulated environment.[269] Researchers can modify the rules, attributes, or parameters of the model to observe how changes impact the system and its outcomes.[270] This allows for the evaluation of different strategies and interventions, providing insights into social behavior. [271] As a result, ABM has the potential to inform evidence-based decision-making,

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262. CM Macal & MJ North, *Tutorial on Agent-Based Modelling and Simulation*, 4 J. SIMULATION 151, 152–54 (2010). *See generally* ROMANOWSKA, WREN, & CRABTREE, *supra* note 254, at 21–22.

263. Macal & North, *supra* note 262, at 155. *See generally* ROMANOWSKA, WREN, & CRABTREE, *supra* note 254, at 35–39.

264. Macal & North, *supra* note 262, at 154–55. *See generally* ROMANOWSKA, WREN, & CRABTREE, *supra* note 254, at 49–57.

265. Macal & North, *supra* note 262, at 152. *See generally* ROMANOWSKA, WREN, & CRABTREE, *supra* note 254, at 23–41.

266. There is not a comprehensive guide to race studies with ABM, but it is the hope of the author that this article will contribute to creating such a guide.

267. ROMANOWSKA, WREN, & CRABTREE, *supra* note 254, at 4–5.

268. *Id.* at 9–10.

269. *See id.*

270. *Id.*

271. *Id.* at 4.

policy formulation, and social change efforts. However, it is important to note that ABM also comes with challenges and limitations. Developing an accurate and valid ABM requires careful consideration of the model's assumptions, data availability, and validation against real-world observations.[272] Additionally, the computational demands of ABM can be significant, especially when dealing with large-scale systems or complex interactions.[273] Model calibration, validation, and sensitivity analysis are crucial to ensure the reliability and robustness of the findings.[274]

ABM provides then a unique lens through which to examine race by modeling the behaviors and interactions of individual agents within a broader social context. These agents, representing individuals, organizations, or institutions, possess autonomy, decision-making capabilities, and the ability to adapt and learn from their environment. By simulating the interactions among these agents, ABM captures the complexity and dynamics of racial systems, shedding light on the emergent properties, feedback loops, and nonlinear patterns that shape racial phenomena. This approach recognizes the agency of individuals and acknowledges that race is not solely determined by systemic forces but also influenced by the choices and interactions of diverse actors within the system.

Of particular interest in race studies is ABM's ability to incorporate historical context and complex causal mechanisms.[275]

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272. John Hotchkiss, Divya Vahra, & So O'Neil, *The Promise of Agent-Based Modeling for Equity-Centered Research*, 42 J. POL'Y ANALYSIS & MGMT. 594, 596–97 (2023).

273. ROMANOWSKA, WREN, & CRABTREE, *supra* note 254, at 6 ("Intuitively, we may be able to understand the interactions between two or among perhaps three individual who follow one or two rules of behavior. But with increasing quantities of individuals and the different processes that influence them, analyzing these interactions becomes intractable for any analog method. This is where computers enter the stage as the main tools used in complexity science. In a simulation, we are able to outsource to a computer's processor the impossible task of keeping track of thousands of parallel computations. This is a task well beyond the cognitive ability of our own brains but which computers excel at. It is therefore not surprising that the rise of simulation and complexity science trailed closely behind the development of computers and their ever-increasing computational power.").

274. *Id.* at 39–41 (describing the limitations of a computational model used as an example in the book).

275. The impact of ABM in the anthropological field demonstrates its ability to capture overlooked historical facts and use them to explore the lives of persons who lived, even in the ancient world:

Historical factors, such as institutional legacies, policies, laws, and discriminatory practices, have profound and lasting effects on contemporary racial dynamics. ABM enables researchers to integrate historical data into models, simulating the impact of past events and policies on present-day racial disparities. By accounting for historical contingencies, ABM helps uncover the persistent and intertwined mechanisms that perpetuate racial inequality. This temporal dimension allows for a deeper understanding of the long-term consequences of historical factors, contributing to more accurate and informed analyses within CRT. ABM not only enhances our understanding of racial dynamics but also holds the potential to inform transformative change. Through simulations and scenario testing, researchers can explore the outcomes of various interventions and policies on racial disparities. This enables policymakers and activists to identify leverage points and design evidence-based strategies that address the systemic roots of racial inequality. ABM provides a platform for dialogue and collaboration between researchers, policymakers, and communities affected by racial disparities, promoting more effective and informed efforts towards achieving racial justice and equity.

2. NetLogo and the Application of Complexity Science

To further research in complexity, a group of complexity thinkers developed NetLogo, a powerful and popular multi-agent modeling software that is widely used in various fields, including social sciences, biology, economics, and ecology.[276] It provides a platform for

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> In the past few decades, scientists have been able to build theoretical frameworks and sophisticated hypotheses by testing them against available data with the aid of advanced computational techniques, in particular, simulation modeling. In archaeology and historical disciplines, simulation modeling gives us a way of observing the possible lives of people in the past and analyzing our theories about them. These *in silico* experiments can help us test and refute hypotheses, investigate the causal mechanism underlying societal transformations, and better focus data collection to help us answer the key questions.

ROMANOWSKA, WREN, & CRABTREE, *supra* note 254, at 4.

276. *See* URI WILENSKY & BILL RAND, AN INTRODUCTION TO AGENT-BASED MODELING: MODELING NATURAL, SOCIAL, AND ENGINEERED COMPLEX SYSTEMS WITH

designing, simulating, and analyzing ABMs, allowing researchers to explore and understand complex systems.[277] NetLogo offers an intuitive and visual programming environment, making it accessible to users with different levels of programming experience. Its graphical interface allows users to create and manipulate agents, define their behaviors, and visualize the dynamics of the system in real-time. The core concept of NetLogo revolves around agents, which are represented by individual objects or entities in the model.[278] Agents can be simple or complex, representing various elements of the system being studied, such as individuals, groups, animals, or even abstract concepts. Each agent has its own set of attributes, rules, and interactions, allowing for the modeling of diverse behaviors and relationships. NetLogo provides a rich set of built-in functions and tools that enable researchers to define the properties and actions of agents, set up the environment, and specify the rules governing the system's dynamics. Users can create custom procedures and functions to implement complex behaviors and decision-making processes for the agents. The software also supports the incorporation of external data and models, allowing for more advanced and realistic simulations.[279]

One of the key features of NetLogo is its ability to visualize the simulation in real-time. Researchers can observe the dynamic behaviors and interactions of agents as the simulation progresses, enabling them to gain insights into the emergent properties and patterns of the system. The visualizations can include graphical representations, charts, plots, and maps, making it easier to interpret and analyze the results of the simulation. NetLogo also supports experimentation and sensitivity

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NETLOGO, at xii (2015); Uri Wilensky, *References,* NETLOGO, https://ccl.northwestern.edu/netlogo/references.shtml (last visited Jan. 26, 2024).

277. *See* Uri Wilensky, *What is NetLogo?*, *NetLogo User Manual Version 6.4.0*, https://ccl.northwestern.edu/netlogo/faq.htht (Nov. 15, 2023).

278. The user manual explains, "NetLogo is particularly well suited for modeling complex systems developing over time. Modelers can give instructions to hundreds or thousands of 'agents' all operating independently. This makes it possible to explore the connection between the micro-level behavior of individuals and the macro-level patterns that emerge from their interaction." *Id.*

279. "Extensions provide additional NetLogo language primitives that can be used in NetLogo models, for doing any of a wide variety of things, from programming with more sophisticated data structures (like networks and tables) to capturing video from a webcam." Uri Wilensky, *Extension Manager Guide, Netlogo User Manual Version* 6.4.0, https://ccl.northwestern.edu/netlogo/faq.htht (Nov. 15, 2023).

analysis. Researchers can run multiple simulations with different parameter settings, initial conditions, or intervention strategies to explore the impact on the system's behavior and outcomes. This capability allows for the testing of hypotheses, the evaluation of alternative scenarios, and the identification of critical factors that influence the system's dynamics. Additionally, NetLogo has an active and supportive community, with a vast library of models and resources available for users to learn from and build upon. Users can share their models, collaborate with others, and contribute to the growing body of knowledge in the field of agent-based modeling.

3. The Example of the Artificial Anasazi

A well-known example of the application of NetLogo in social science that demonstrates its power is the replication of the "Artificial Anasazi" in NetLogo.[280] The "Artificial Anasazi" model is a seminal work simulating and studying the dynamics of the ancient Anasazi civilization.[281] To explore the causes of the collapse of the Anasazi society in the American Southwest, researchers developed an ABM model to simulate the behavior of individual Anasazi households and their interactions within a complex socio-ecological system.[282] The model incorporated various factors such as resource availability, agricultural practices, population growth, and social networks to capture the dynamics of the Anasazi society.[283] In response to these parameters, several researchers took advantage of NetLogo's flexibility and ease of use to recreate the "Artificial Anasazi" model in NetLogo.[284]

280. Marco A. Janssen, *Understanding Artificial Anasazi*, 12 J. ARTIFICIAL SOC'YS & SOC. SIMULATION ¶ 1.2 (2009); Forest Stonedahl & Uri Wilensky, *NetLogo Models Library: Artificial Anasazi Model*, NETLOGO, https://ccl.northwestern.edu/netlogo/models/ArtificialAnasazi (last visited Jan. 26, 2024).

281. Robert L. Axtell, Joshua M. Epstein, Jeffrey S. Dean, & George J, Gumerman, *Population Growth and Collapse in a Multiagent Model of the Kayenta Anasazi in Long House Valley,* 99 PROC. NAT'L ACAD. SCIS., 7275 (2002); *see also* ROMANOWSKA, WREN, & CRABTREE, *supra* note 254, at 12 ("NetLogo is the most popular AMB platform among archaeologists . . . and also has relatively readable code, which means that it is at least superficially understandable to human readers, even non-modelers); SMALDINO, *supra* note 254, at xiii (2023) ("NetLogo is a useful and widely adopted software package and language for building and analyzing agent-based models.").

282. Axtell, Epstein, Dean, & Gumerman, *supra* note 281, at 76–78.

283. For a description of the original "Artificial Anasazi" model, see *id.* at 72–76.

284. *See* Stonedahl & Wilensky, *supra* note 280.

Researchers used the NetLogo programming language to define the behavior of the individual agents (Anasazi households) and their interactions with the environment and other agents.[285] They specified rules for resource collection, agricultural practices, migration, and social interaction, among other factors.[286] The NetLogo interface allowed the researchers to visualize the simulation in real-time, observing the changing patterns of settlement, resource consumption, and social interactions among the Anasazi households.[287] They were able to analyze the emergent properties of the system, such as the distribution of wealth (measured in sugar in the model), population density, and sustainability of the society.[288] By running various scenarios with different parameter settings and initial conditions in NetLogo, the researchers were able to confirm the initial "Artificial Anasazi" model's findings: environmental factors alone could not explain the society's collapse.[289] They observed that other factors, like population growth and the interaction between households, played a significant role in the collapse.[290]

The Artificial Anasazi project demonstrates the power of using NetLogo as a tool for modeling and understanding complex socio-ecological systems. The software provides a platform for implementing the ABM framework, simulating the behavior of individual agents, and visualizing the outcomes of the simulation. NetLogo's flexibility and user-friendly interface facilitated researchers' ability to explore and analyze the dynamics of the Anasazi society and draw insights into the causes of its collapse. Overall, the Artificial Anasazi project highlighted the capabilities of NetLogo as a valuable tool for agent-based modeling, enabling researchers to simulate and study complex systems, including socio-ecological dynamics. The NetLogo-based model of the Anasazi civilization suggests the way that Netlogo can provide valuable insights into the factors contributing to social structure and function.

285. *Id.*; Janssen, *supra* note 280, ¶¶ 2.2–2.6.
286. Stonedahl & Wilensky, *supra* note 280; Janssen, *supra* note 280, ¶¶ 2.2–2.6.
287. Janssen, *supra* note 280, ¶¶ 2.3–2.15.
288. *Id.*
289. *Id.* ¶ 5.1.
290. *Id.*

C. Case Studies and Examples

This section provides three concrete examples where complexity science has been applied to social science with direct implications for race studies. The goal here is two-fold. First, to suggest the evolution and scope of the influence of complexity science in race studies. This is necessary because the field of complexity science has not always been explicit or clearly defined.[291] The second goal is to encourage scholarship in a wide variety of areas where complexity science may help researchers and policymakers understand the hidden forces at work in constructing and maintaining race as a social phenomenon.

1. The Schelling Segregation Model

The Schelling Segregation Model is a venerable study of the social physics of segregation.[292] Since it was written in the late 1970s, it has produced substantial scholarship; more recently, it has become a useful teaching model included as a standard example in NetLogo.[293] It can be redescribed as an illustration of ABM, although it was created long before ABM was developed.[294] The Segregation Model was developed by economist Thomas C. Schelling, who sought to bridge the gap between microeconomics and a wide array of social predicaments. In the 1960s, he boldly set out to decipher the enigma of racial segregation—an issue that, while somewhat less contentious today, continues to loom large in the realms of public health and social science. What underpins the emergence of racial segregation? Curiously, most individuals disavow any intention to inhabit racially isolated neighborhoods, yet the persistent reality contradicts their professed desires. How can we unravel this conundrum?

At its core, the Schelling Segregation Model poses a fundamental question that has perplexed both public health specialists

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291. *See* MITCHELL, *supra* note 29, at 94–111 (discussing why it is hard to define complexity science).

292. *See generally* THOMAS SCHELLING, MICROMOTIVES AND MACROBEHAVIOR (1978) (original work detailing the Schelling Segregation Model).

293. For a description of the model and implementation in NetLogo, see SMALDINO, *supra* note 254, at 53–81.

294. *See id.* at 63–69.

and social scientists alike: What are the underlying causes of racial segregation?[295] This question is complicated by a gap between explicit attitudes versus collective action: it is rare, for example, to encounter individuals who explicitly proclaim a preference for living in racially isolated neighborhoods, and yet, such segregation persists—casting a shadow over our collective aspirations for inclusivity and diversity. [296] To study this phenomenon, Schelling ingeniously devised a deceptively simple game, unfolding within the confines of a checkerboard graph—a visual representation that mirrors the chessboard of human interactions. The original model was implemented mechanically.[297] It took the form of a game that begins as two distinct types of "chips" are scattered randomly across the board—an ensemble of disparate elements that mirrors the complexity of our society.[298] Think of this as a game board where the chips are like checkers, representing people living near each other in a town. They have colors, which represent racial differences. The game plays out in turns. The chips fill the board, with each chip surrounded by other chips. If they are surrounded by chips of the same color, they stay where they are, but if they have different color chips, they may relocate. What this game finds is that even when the chips have slight preferences for sameness, over several moves, the chips move into segregated patterns. Schelling's game demonstrates how societies organically evolve into tightly knit, segregated neighborhoods.[299] Surprisingly, this process does not emanate from a conscious desire for explicit separation or an insidious quest for numerical dominance. Instead, it springs from an innate desire to have a neighbor or two who are of the same race.[300] Schelling showed that even devoid of racial prejudice, slight preference for sameness results in the pervasive phenomenon of social sorting.[301] The Schelling

295. *See* SCHELLING, *supra* note 292, at 138.

296. Tracey Hadden Loh, Christopher Coes, & Becca Butte, *The Great Real Estate Reset*, BROOKINGS (Dec. 16, 2023), https://www.brookings.edu/articles/trend-1-separate-and-unequal-neighborhoods-are-sustaining-racial-and-economic-injustice-in-the-us/. The preference for diversity was an assumption of the Schelling model. *See* SHELLING s*upra* note 293, at 146–47.

297. SCHELLING, *supra* note 292, at 147–57.

298. *Id.* at 148–49 (describing the "chips" Schelling uses as dimes and pennies).

299. SMALDINO, *supra* note 254, at 76.

300. *See* SCHELLING, *supra* note 292, at 161–65.

301. *See* SMALDINO, *supra* note 254, at 76.

Segregation Model is easily modeled with Netlogo.[302] It serves as a powerful testament to the potential of ABM, offering profound insights into the intricate dynamics that underlie our collective human experience.

2. Complexity Science and Healthcare Inequities

In recent years, there has been a growing recognition of the intricate role that complexity plays in shaping public health and public policy. This awareness has instigated a methodological shift toward complexity science that has been called the "complexity turn" in public health.[303] This refers to a broad recognition that ABM is a powerful tool that enables the simulation of individuals, their behaviors, interactions, and their social and physical environments. A recent study provides a systematic review of the use of ABM to examine the generation or

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302. *Id.* at 63–69.

303. Public health scholarship has been making use of complexity science and agent-based modeling with increasing interest. One study notes:

> Complex systems are systems which consist of interacting parts or subsystems. Some key characteristics of complex systems are dynamic, resulting in adaptation to change, non-linear relationships, feedback loops, tipping points, and the emergence of macro- phenomena from interactions at the micro level. It is difficult to capture these relationships using a traditional epidemiological "risk factor" approach which uses linear reductionist models to test the relationships between decontextualised dependent and independent variables. Agent-based modelling (ABM), a well-established methodological approach used widely in the field of social science, has been highlighted as a methodological approach that can be used to address this problem. ABM involves simulating the actions and interactions of individual agents with other agents and their environment based on a set of specified rules and observing emergent phenomena. Agents may adapt their own behaviour in response to previous behaviour, their social network, or environmental stimuli. Not only can ABM be used to understand complex phenomena, but they can also be used to test the impact of policy interventions and in- form policy decisions and have been successfully applied in other areas of public health, particularly for the control of infectious diseases.

Jennifer Boyd, Rebekah Wilson, Corinna Elsenbroich, Alison Heppenstall, & Petra Meier, *Agent-Based Modelling of Health Inequalities following the Complexity Turn in Public Health: A Systematic Review*, INT'L J. ENV'L RSCH. & PUB. HEALTH, Dec. 14, 2022, at 2 (citations omitted).

persistence of health inequalities, shedding light on its potential contributions to our understanding of socioeconomic disparities in health.[304] The findings of the review underscored the growing impact of ABM in unraveling the socioeconomic complexities underlying health inequalities. While most models examined health behaviors, it is important to note that these behaviors serve as critical mediators linking social determinants to health outcomes. By simulating individual choices related to diet, for instance, ABM can help elucidate the underlying mechanisms driving disparities in nutrition and subsequent health outcomes.[305] However, the review also reveals an important research gap in the field. Despite the progress made in understanding health behaviors, there is a pressing need for ABM studies that delve into the social and economic drivers of health inequalities.[306] Such investigations hold the potential to illuminate the intricate interplay between socioeconomic factors, health behaviors, and health outcomes, providing policymakers with invaluable insights to address disparities effectively.

The increasing focus on complexity in public health and public policy domains has spurred the adoption of computational approaches, with ABM emerging as a valuable tool to explore health inequalities. This systematic review highlights the contributions made by ABM in comprehending the multifaceted nature of socioeconomic disparities in

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304. *Id.* at 1–2.

305. *See id.* at 13 (collecting papers that have used ABM to model the socioeconomic differences in dietary behaviors and tested the impact of educational campaigns on various food behaviors).

306. The study concludes:

> Efforts thus far to use ABM to understand socioeconomic inequalities in health have focused on the contribution of health behaviour. However, this focus on health behaviour is at odds with calls from researchers to "move beyond bad behaviours" and the position of influential public health organisations. For example, the WHO concluded that it is the underlying social and economic factors that determine health and health inequalities as opposed to health behaviours. We are increasingly aware that health inequalities are not only the result of differences in health behaviour, yet little has been done using ABM to attempt to understand the complex relationships between the social and economic environment people live in and the influence on their health via pathways other than health behaviour.

Id. at 12–13 (citations omitted).

health. Nonetheless, there is a need for further research that delves into the social and economic determinants of health inequalities using ABM. By bridging the gap between theory and practice, ABM can empower policymakers to develop evidence-based interventions that target the root causes of health disparities, ultimately fostering a more equitable society.

3. Incarceration as an Infectious Disease

Another example of complexity science in race scholarship with a public health dimension is a 2014 study that seeks to understand the nature of imprisonment using an agent-based model to explain racial disparities in incarceration rates. A study titled "The Contagious Nature of Imprisonment: An Agent-Based Model to Explain Racial Disparities in Incarceration Rates" presents an agent-based model that employs the well-established susceptible-infected-susceptible (SIS) framework used in the study of infectious diseases to shed light on the intricate workings of incarceration.[307] Its primary focus lies in elucidating the racial disparities prevalent in the rates of imprisonment between Black and white Americans, attributing them to differential sentencing practices targeting these distinct demographic groups.[308] By incorporating the notion of a social influence network through which incarceration can propagate, the study unveils the profound impact that even minor discrepancies in sentencing can have on the resulting disparities in incarceration rates.[309]

To ensure the robustness of its findings, the study controls for key factors, such as transmissibility, susceptibility, and the structure of the influence network.[310] The authors' model reproduces the significant racial disparities in incarceration rates that are observed in the real world, considering the differing sentence lengths imposed on white and Black individuals convicted of drug offenses in the United States.[311]

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307. Kristian Lum, Samarth Swarup, Stephen Eubank, & James Hawdon, *The Contagious Nature of Imprisonment: An Agent-based Model to Explain Racial Disparities in Incarceration Rates*, 11 J. ROYAL. SOC'Y. INTERFACE 1, 1 (2014).

308. *Id.*

309. *Id.* at 11.

310. *Id.* at 1.

311. *Id.* at 2.

Importantly, their model achieves this impressive feat without necessitating tracking individuals over time.[312] Furthermore, by closely examining the emergent structural patterns of recidivism, the authors demonstrate that these patterns are an inherent consequence of their model, mirroring the empirical data on incarceration in the state of California with remarkable fidelity.[313] This work represents a significant stride in advancing interdisciplinary efforts at the intersection of epidemiology and criminology. By synergizing theories and methodologies from these distinct fields, the study strives to deepen understanding of the complex dynamics underlying the carceral system.[314] Ultimately, the research aims to foster more comprehensive insights into the multifaceted factors contributing to racial disparities in incarceration rates, thereby paving the way for evidence-based policy interventions and social reforms.[315]

The agent-based model used in the simulation encompasses three pivotal components: a synthetic population serving as the conduit for the "disease" transmission; probabilities of transmission; and durations of infectivity.[316] The simulation endeavors to create a realistic, multi-generational population of agents, with meticulously known familial and friendship connections.[317] Notably, the parameters employed in generating this population are derived from recent, high-quality data sources.[318] For instance, vital distributions such as sex, lifespan, and the number of offspring for each agent are sourced from reputable entities like the U.S. Census, the Centers for Disease Control and Prevention, and the Social Security Administration, respectively.[319] To determine transmission probabilities, the study turns to an extensive survey conducted among prison inmates, as presented in a scholarly work.[320] This survey offers insights into the likelihood of an inmate's

312. *See id.* at 3.
313. *Id.* at 5.
314. *See id.* at 11
315. *Id.* at 1.
316. *Id.* 3–5.
317. *Id.* at 3–4.
318. *Id.* at 3.
319. *Id.*
320. *Id.*

mother, father, sister, brother, or adult child also being incarcerated, classified according to the gender of the inmate.[321]

In summary, complexity science has made meaningful contributions to the study of race by providing new tools and perspectives for understanding complex social phenomena. As illustrated by the examples discussed, ABM enables researchers to simulate individual behaviors and interactions to reveal the emergent patterns that underlie issues like segregation, health inequities, and mass incarceration. While currently modeling health behavior is the most popular use for ABM, there is great potential for future research to examine the root socioeconomic drivers of racial disparities across multiple domains. By adopting ABM, scholars can gain deeper insight into the dynamic forces that perpetuate racism on systemic levels. This complexity-informed research will be critical for identifying high-leverage policy solutions capable of catalyzing lasting structural reforms. With the enhanced perspectives achieved with ABM, researchers will be better equipped to untangle the intricate workings of racism and pursue transformative social change built on equity and justice.

IV. TOWARDS A THEORY OF EMPIRICAL CRITICAL RACE THEORY

A complete theory of law that unites contemporary empirical techniques would include insights from information science, complexity science, and Bayesian probability.[322] It would integrate the

321. *Id.*

322. Although such a theory does not exist yet, some scholars have made propaedeutic introductions to such a theory. *See, e.g.*, J.B. Ruhl, *Law's Complexity: A Primer*, 24 GA. ST. U.L. REV. 885 (2008). There have been many papers that describe the advantages of complexity science for various areas of law. *See, e.g.*, Murray, Webb, & Wheatly, *supra* note 200; LAW AS DATA, *supra* note 200. But a fully developed general theory of law does not yet exist. Ronald Allen made some useful comments about what a general theory of law that acknowledges complexity might be like in Ronald J. Allen, *Rationality and the Taming of Complexity*, 62 ALA. L. REV. 1047 (2011), where he argues that understanding the legal system through the lens of complexity provides valuable insights into various phenomena, revealing similarities between seemingly unrelated aspects. By adopting this perspective, the challenges the law faces concerning both legal and factual questions become clearer. The concept of "taming complexity" proves to be an encompassing viewpoint for him, shedding light on various aspects of dispute resolution and trials. *Id.* at 1058–59. Moreover, he believes that it has implications for practical and philosophical debates about the essence of law, the significance of discretion,

philosophical implications of these sciences with the critical stance of CRT. Information science and complexity science might enrich CRT by providing a rich and nuanced social theory that bears significant insights into issues of critical concern to race scholars. A complete theory of race would not prescind from a single, high-level theory and description of laws, as the early social physicists believed. It would be a symphony of theories about mid-level processes that could be verified by reference to social data. A granular study of the social world would drive insights into the construction of race in particular settings and social structures.

This essay describes how complexity science yields new insights into social ontology, suggesting some critical features for eCRT as a new social science of race. Here then is a summary of some specific implications of applying complexity science to CRT, given the features that have been described in this essay:

1. *Social theories are incomplete.* Complexity theory suggests heterogeneity among types of social ontology. Social phenomena are created by humans, whose beliefs, biases, attitudes, emotions, and modalities of reason shape their lived experience of meaning. As Daniel Little has written,

> [t]he upshot is that a complex social whole exceeds the particular theories we have created for this kind of phenomenon at any given point in time. The social whole is composed of lower-level processes; but it is not exhausted by any specific list of underlying processes. Therefore, we should not imagine that the ideal result of

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and perennial issues like the distinction between rules and standards or rules and principles. *Id.* at 1048–49. He does not, however, cite to social theorists like DeLanda and Cilliers or describe the connections to poststructuralism that have been described in this essay. Also, the implications of Kolmogorov complexity are not a part of his analysis. *See* Daniel Martin Katz, Corinna Coupette, Janis Beckedorf, & Dirk Hartung, *Complex Societies and the Growth of the Law*, 10 SCI. REP. 1, 1 (2020) (arguing that the growth of diversity and interconnectedness within society engenders a parallel evolution in the realm of legal norms); Daniel Katz & Michael Bommarito II, *Measuring the Complexity of the Law: The United States Code*, 22 ARTIFICIAL INTEL. & L. 337, 337 (2013) (developing an empirical framework for measuring relative legal complexity based on "knowledge acquisition, an approach at the intersection of psychology and computer science that takes into account the structure, language, and interdependence of law . . . as a first step in developing a practical methodology for assessing legal complexity").

> investigation of urban phenomena is a comprehensive theory of the city; the goal is chimerical. Social science is always "incomplete," in the sense that there are always social processes relevant to social outcomes that have not been theorized.[323]

The implications of the incompleteness of social theory are profound. They suggest a post-liberal approach that recognizes the contingency of social thought and the need constantly to reassess theories in light of their consequences. Race scholars have consistently defied attempts to reduce the lived realities of human lives to the brute facts of social data. In an age where social data is used to construct identities of persons for commercial exploitation, the need to be wary of reduction—to tell the stories of the lived experiences of person who experience the world constructed through and by social institutions, particularly law—remains essential to social justice.

2. *An assemblage approach*. Mindful of the caveats regarding incompleteness of social theories, eCRT should embrace an assemblage approach. Social systems are collections of coupled subsystems with many influences. If a siloed approach to studying social phenomena denies this fact, then it will not be able to fully make use of the insights that can be gained by the information revolution. Finding patterns among diverse data sets will rely on social theories that recognize the legitimacy of those insights. The value of this approach is already bearing fruit in healthcare policy, where assemblage theory is recognized. Beyond this critical scholarship, race studies will benefit from better understanding of how systemic racism is constructed and maintained through coupled systems of law, politics, economics, and environment. This is a trenchant issue. The connections among systems and subsystems may well become much more accessible for social science in the age of artificial intelligence ("AI"), which may soon design models and interpret their outcomes. It may well be the case that in these AI systems will be able to construct multidimensional models of interrelated systems that far exceed the limits of human

323. LITTLE, *supra* note 12, at 10.

intelligence.[324] What insights into structural racism can be gleaned from the new ways in which AI and human experts can work together synergistically to solve complex problems? But, achieving this goal will require acknowledging the value of an assemblage approach to social science.

3. *Causation in social systems.* Since social phenomena are typically influenced by a multitude of interconnected factors, causation operates within intricate multidimensional social space. The view advanced in the essay emphasizes the importance of understanding the social context, historical dynamics, and institutional structures that shape causal relationships in social science research. This insight promised to reform contemporary research methods. For example, to the extent that statistical analysis is used in race studies, it often is engaged in time-series analysis that assumes linear systems. Linear regression analysis, a common technique, assumes a linear relationship between the variables in a social system.

The nonlinearity of complex systems could enhance and revise some aspects of this research in a number of ways. As was described in this essay, nonlinear systems theory recognizes that interactions between variables can be nonlinear, while linear regression assumes that the relationships between predictors are additive and independent, neglecting the potential for nonlinear interactions. In nonlinear systems, the effect of one variable on the response may depend on the values or interactions of other variables. This shift in perspective implies significant differences in theory and application. Moreover, since nonlinear systems theory recognizes that complex phenomena often have multiple causes and feedback loops, making it challenging to isolate and attribute effects to individual predictors, the single-variable relationships assumed in linear regression models are inadequate because they do not explicitly address multicausality. Finally, nonlinear systems theory recognizes that systems can exhibit non-stationarity, where the statistical properties and relationships between variables change over time. Linear regression assumes stationarity, assuming that relationships between variables remain constant, which may not hold in nonlinear systems.

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324. *See, e.g.*, Kevin Heng, *Approximating Reality,* 111 AM. SCIENTIST, 198, 199 (2023).

4. *Structural realism.* This essay has emphasized structural realism as it might be applied in race scholarship. The cautious limits on comprehensive theories and overly ambitious social ideology are not a plea for anti-realism. Indeed, complexity science is firmly rooted in a commitment to realist views of information and social ontology. Information exists as a relational reality, and social groups can be described in part because of this. The Supreme Court exists, the Congress exists, the township and church congregation exist. They have structures that information science can help to describe. Their realism lies not in essences but in relations that form social structures that evolve and change over time. This is a strongly anti-essentialist view that nonetheless does not fall into solipsism or nihilism.

CONCLUSION

Complexity science fits well with core values of CRT. It challenges the notion that social categories like race have fixed, universal, and inherent characteristics. From a complexity perspective, social identities are complex and intersectional, and they are shaped by historical, social, and cultural contexts. It emphasizes the fluidity and contingency of identities, rejecting the idea that there is a singular and essential experience shared by all members of a particular racial or ethnic group. Moreover, it embraces the concept of intersectionality by highlighting how multiple social categories (such as race, gender, class, sexuality, etc.) intersect and interact to shape individual experiences and social inequalities. Traditional approaches to social science can undermine the intersectional lens by reducing complex identities to a single characteristic and failing to account for the diverse experiences and perspectives within a particular group. Complexity science can emphasize that race is not a fixed and objective biological reality but rather a socially constructed concept. By focusing on the concept of assemblage, complexity science emphasizes that race and racial categories are products of historical, political, and cultural processes, and they vary across different contexts.

It is important to emphasize that complexity science is not a complete social theory, and indeed it suggests that a complete theory is impossible to achieve. Complexity science suggests that social science can never be an ideology in itself. This is suggested by the limitations on description implied by nonlinear scaling and the limits of

information compressibility. Narrative can help to address these limits by providing insights that exceed the limits of rule-based approaches to analysis. Since narratives give insight into lived experience, they bridge the gap between philosophical inquiry and the interpretation of historical events through the medium of narrative. Narratives enable us to construct meaningful frameworks and provide coherence to our experiences.

A promising resource for research in this regard is the philosophy of Paul Ricoeur (1913–2005), a French philosopher, whose work in hermeneutics, phenomenology, and narrative theory continues to be influential.[325] Ricoeur was deeply intrigued by the role of narrative in shaping human identity, history, and ethics. He crafted his magnum opus, the triumphant trilogy aptly titled *Time and Narrative*, which stands as an indomitable force within this domain. [326] Ricoeur's philosophical thought was characterized by a deep concern for ethics and human values. He believed that philosophy should engage with practical and ethical questions, particularly in relation to the question of how humans should live together in a just society.

Gleick concludes his book on information with a comment on Jorge Louis Borges's *Library of Babel* that can serve as a credo for this essay.[327] In his compelling narrative, Borges beckons readers into an intricately woven cosmos, the Library of the Biblical Babel, which he asserts as a profound symbol of both tumultuous disorder and boundless potentiality. Borges's Library is evocative of the Promethean and Orphean symbolism of Nature that were evoked by Heraclitus in the epigraph that begins this essay. Within the sprawling walls of the Library, which extends infinitely, housing an inconceivable multitude of books that encompass every conceivable arrangement of letters and words, the librarians' relentless quest for understanding becomes a reflection of our own innate human longing for comprehension amidst the chaos of existence. Gleick writes:

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325. For an introduction to Paul Ricoeur, see David Pellauer & Bernard Dauenhauer, *Paul Ricoeur*, STAN. ENCYC. PHILOSOPHY, https://plato.stanford.edu/archives/win2022/entries/ricoeur/ (Dec. 15, 2022).

326. PAUL RICOEUR, TIME AND NARRATIVE, VOLUME I, (Kathleen McLaughlin and David Pellauer trans., 1984).

327. Jorge Louis Borges, *The Library of Babel*, *in* FICCIONES (Anthony Kerrigan, ed. 1994).

> We walk the corridors [of the Library] searching the shelves and rearranging them, looking for lines of meaning amid leagues of cacophony and incoherence, reading the history of the past and the future, collecting our thoughts and collecting the thoughts of others, and every so often glimpsing mirrors, in which we may recognize creatures of information.[328]

328. GLEICK, *supra* note 74, at 426.