MAKING A CASE FOR GENETICS: INTERDISCIPLINARY VISIONS AND PRACTICES IN THE CONTEMPORARY SOCIAL SCIENCES

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ABSTRACT

Purpose – *This chapter compares interdisciplinary research that engages genomic science from economics, political science, and sociology. It describes, compares, and evaluates concepts and research findings from new and rapidly developing research fields, and develops a conceptual taxonomy of the social environment.*

Methodology/approach – *A selection of programmatic and empirical articles, published mostly since 2008 in leading economics, political science, and sociology journals, were analyzed according to (a) the relationship they pose between their discipline and genomic science, (b) the specific empirical contributions they make to disciplinary research questions, and (c) their conceptualization of the "social environment" as it informs the central* problematique *of current inquiry: gene-environment interaction.*

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Findings – *While all three of the social science disciplines reviewed engage genomic science, economics and political science tend to engage genomics on its own terms, and develop genomic explanations of economic and political behavior. In contrast, sociologists develop arguments that for genomic science to advance, the "environment" in gene-environment interaction needs better theorization and measurement. We develop an approach to the environment that treats it as a set of measurable institutional (rule-like) arrangements, which take the forms of neighborhoods, families, schools, nations, states, and cultures.*

Research/implications – *Interdisciplinary research that combines insights from the social sciences and genomic science should develop and apply a richer array of concepts and measures if gene-environment research – including epigenetics – is to advance.*

Originality/value – *This chapter provides a critical review and redirection of three rapidly developing areas of interdisciplinary research on gene-environment interaction and epigenetics.*

Keywords: Gene-environment interaction; epigenetics; genopolitics; genoeconomics; sociogenomics

INTRODUCTION

Within five years of the completion of the first complete draft from the Human Genome Project (HGP), social scientists were actively debating whether and how their disciplines should engage with genetic science. In one set of engagements, genetic knowledge and its social and political consequences emerged as social facts of focal interest. At the same time, in both conceptual and empirical papers published in leading journals, social scientists began to advocate for the utility of genetic concepts, deploy behavioral genetic and candidate gene study methodologies, and promulgate visions of hybrid knowledge production practices with accordingly hybrid names, such as genoeconomics, genopolitics, and sociogenomics. Based on an analysis of the peer-reviewed literature, our chapter examines these novel hybrid visions and engagements in three social sciences: economics, political science, and sociology.[1]

We find both similarities and differences across these disciplines. First, each discipline has "genetics entrepreneurs," that is, social scientists who develop research agendas meant to persuade their colleagues of the utility of genetic concepts and/or methodologies for their discipline. In each discipline, part of the work of entrepreneurs is to position genetics as a set of techniques that offer new ways of answering questions at the center of the discipline.

There is a remarkable degree of interdisciplinary collaboration among genetics entrepreneurs, who not only collaborate with life scientists but with like-minded social scientists across disciplines. Such collaboration was institutionalized in 2011, with the founding of the international Social Science Genetics Association Consortium (SSGAC).[2] The SSGAC has been a major site for interdisciplinary exchange by hosting meetings, offering training, and coordinating international efforts to leverage large cohort studies to advance the agendas of genoeconomics, genopolitics, and sociogenomics.

These similarities and collaborations notwithstanding, sociologists uniquely make a strong argument that *genetics needs sociology* to develop further as a science. This argument is based on the centrality of "the environment" in gene-environmental interaction, the conceptual paradigm currently at the center of genetics, and especially epigenetics research. Specifically, sociologists assert that the HGP has had the unintended consequence of demonstrating how important the social environment is to human health; further, they note, sociology is the discipline with the most experience and expertise in developing nuanced and valid measures of the social environment. We outline this argument and point to the unique and important role of medical sociologists in defining the terms of sociology's engagement with contemporary genetic research.

Importantly, this engagement can contribute a systematic analytical framework for conceptualizing what the environment is, and what it does. We outline such a framework, moving from an abstract discussion of how the social environment has effects through inequality (arguably the core focus of sociology), to a more specific discussion of social environmental concepts at the meso- and macro-levels of analysis. We conclude by highlighting currents and contradictions for gene-environment research that is turning toward epigenetics.

HYBRID VISIONS: GENOECONOMICS, GENOPOLITICS, AND SOCIOGENOMICS

In the first decade of the new millennium, social scientists across the disciplines of economics, political science, and economics began to actively grapple with whether and how they might want to engage with molecular genetics. In each discipline, "genetics entrepreneurs" promulgated specific visions of what such an engagement might bring. These visions endeavored to link the core questions and/or contributions of each discipline to genetic techniques and information. As such, they reflect jurisdictional claims (Abbott, 1988), as well as forward-looking agendas. They also reflect disciplinary histories, which have shaped both the emergence of controversy regarding geno-inflected research agendas and related, social scientists' varied strategies for contending with critique.

Genoeconomics

Economists point to early behavioral genetics studies on "economics outcomes" as their discipline's first engagement with genetics (Benjamin et al., 2012, p. 12). In the mid-1970s, behavioral geneticists first published research on the heritability of income, as assessed in twin studies, which they estimated as ranging from 18 and 41% (Taubman, 1976). Economists' interest in the heritability of "economic preferences" has persisted, although these are now more typically studied in incentivized experiments or surveys. Recent work includes analyses of the heritability of permanent income and of wealth (Benjamin et al., 2012), both longstanding foci of economic research, and the causal effect of poor health on education (Fletcher & Lehrer, 2011).

With the advent of molecular genetic information and technologies, economists began working with data on single nucleotide polymorphisms (SNPs) and collaborating in Gene Wide Association Studies (GWAS). The first candidate gene studies in economics appeared in 2007 (Eisenberg et al., 2007). As observed by Benjamin and colleagues, these early hypothesis driven studies tend to focus on two broad kinds of outcomes, "decision-making under uncertainty or social preferences" (2012, p. 15). Papers authored by economists using GWAS appeared in the literature in 2012, focused on both self-employment and educational attainment as outcomes of interest (Beauchamp et al., 2011; Rietveld et al., 2013; Van der Loos et al., 2013).

The term *genoeconomics* first appeared in 2007, as part of a National Academy of Sciences "survey" of contemporary biosocial research (Weinstein, Vaupel, & Wachter, 2007). Congruent with the focus of the HGP on human health, this initial framing of genoeconomics was oriented primarily to possible intersections between genomics and the subfield of health economics, with its focus on how individual behavior and social institutions influence health outcomes. Consequently, Benjamin et al. (2007) describe genoeconomics as a new "research frontier" and predicted that it would contribute to the discipline by "identifying the many ways in which individual behavior and social institutions moderate or amplify genetic differences."

They articulated their vision for genoeconomics in terms of "promises" and "pitfalls." The promises center on three potential "points of contact" between genomics and economics, which may serve to advance research in both fields:

(1) economics can contribute a theoretical and empirical framework for understanding how individual behavior and economic markets mediate the influence of genetic factors;
(2) incorporating (exogenous) genetic variation into empirical analysis can help economists identify and measure causal pathways and mechanisms that produce individual differences; and
(3) economics can aid in analyzing the policy issues raised by the existence of genetic knowledge and its potential societal diffusion (Benjamin et al., 2007).

Some of the examples offered to illustrate each of these points come from health-related research, with outcomes including, for example, "how social institutions – like the market for cigarettes – interact with genes to jointly generate important health phenotypes like lung cancer." More broadly, they suggest that the "joint study of genetic variation and variation in economic phenotypes" might allow economists to decompose "crude concepts," such as risk aversion, into social and biological (i.e., genetic and neurological) components. They conceptualize this research agenda in terms of identifying genetic contributions to "proximal phenotypes," such as risk aversion, impulsivity, or cognitive function, that are relevant to "distal phenotypes" that are typical foci of economic research, such as labor supply or wealth accumulation. The authors are careful to note that "proximal phenotypes are more likely to be directly associated with underlying genetic propensities and to mediate the relationship between genetic polymorphisms and the distal phenotypes." Nonetheless, the framing of "labor supply," a dimension of social organization, as a "phenotype" – however distal – is quite striking.

In this initial conceptualization of genoeconomics, economists framed as pitfalls both methodological and ethical issues spanning the life course of a study, from the conduct of the research through the dissemination of findings (Benjamin et al., 2007). The methodological issues highlighted include defining proximal phenotypes of interest (especially, as noted above, given that many of the focal interests of economics are likely to be quite distal from genotypes), the correlations between genes and environments and the corresponding need for very large samples to adequately power analyses, and, related, the need to replicate findings which already had appeared as a challenge in biomedical genetic research. The authors note further that the risk that results might not be replicable is simultaneously an ethical issue, requiring that study findings be reported in a circumspect manner. This potential pitfall has been taken quite seriously in subsequent research, with papers in economics journals frequently reporting simultaneously on observed associations and failed attempts at replication in a second or third sample (e.g., Beauchamp et al., 2011).

Conceptualizing genoeconomics in terms of its "promises" and "pitfalls" became formalized in a paper in the 2012 *Annual Review of Economics*. Five years after the original articulation of genoeconomics, the scope of the field has expanded; the authors are oriented broadly to the possibility of "identifying biological mechanisms that influence economic behavior" (p. 3). They are also markedly less focused on the health related outcomes that were at the center of the 2007 paper by Benjamin and colleagues. Rather, their research agenda takes up the possibly biological foundation of preferences (p. 12) and/or traits that are important parts of experimental research models in economics. However, the most striking change over the five years between the two papers is the generation of empirical research projects, drawing on datasets from the US (including the Wisconsin Longitudinal Study and the Framingham Heart Study), Iceland, and Sweden. The authors also announce the founding of a "Gentrepreneurship Consortium," devoted to research on genetic associations with self-employment (van der Loos et al., 2013), which was modeled on the SSGAC. Economists credit the SSGAC with helping them to avoid "problems that geneticists have known about for years" (e.g., the "pitfalls" described above) in designing genoeconomic research (Callaway, 2012, p. 155).

With one notable exception, research at the intersection of genetics and economics has been relatively uncontroversial within economics. That exception was a paper by economists that claimed to find an association between the "genomic diversity" of a country and its "economic success" (Ashraf & Galor, 2013) which was disseminated on the internet and highlighted in advance of its publication in a prestigious science journal (Chin, 2012). The furor surrounding this paper centered on not only the policy implications of the analysis, but the conceptual model and measurements that were its foundation (Callaway, 2012). Both prominent genetics researchers and paleoanthropologists levied the first critiques of the study (Callaway, 2012, p. 155), which were followed by a multi-authored interdisciplinary review which alleged that it was "bad science," compromised by a misunderstanding of central scientific concepts, erroneously operationalized variables, and disregard of relevant findings in the published literature (Guedes et al., 2013; cf. Conley, Fletcher, & Dawes, 2014). The critique did not conclude that social scientists should not use genetic information, but rather that they must "exercise particular caution" in so doing:

> As Benjamin et al. (2007, p. 656) point out, "researchers in this field hold a special responsibility to try to accurately inform the media and the public about the limitations of the science," especially in studies intended for "social-scientific interventions." (Guedes et al., 2013, p. 77)

The attention of genoeconomics advocates to the "pitfalls" and challenges facing their research and their obligations to explaining the limitations of the science stand in rather stark contrast to similarly contentious episodes within genetics (Richardson, 2011). At the same time, the relative lack of controversy about whether genetics itself has a place in economics research is a marked contrast to the emergence of genetics research agendas in political science and sociology.

Genopolitics

Political scientists were focused on the political implications of genetic knowledge before the emergence of a "genopolitical" research agenda. For example, a 2001 paper in the *Annual Review of Political Science* articulated the need to "assess the sociopolitical implications of contemporary biology" and proposed a new field – biopolitics – which would take as its focus points of intersection between politics and biology (Masters, 2001; see also Tygart, 2000).[3] The author outlined an empirical research agenda focused on topics such as the influence of radiation on human genetic material and the regulation of risk and the consequences of environmental toxins for a variety of human predispositions and behaviors. Additionally, he suggested that research in the contemporary life sciences would challenge core assumptions in political theory, including the Lockean view of humans as a "tabula rasa" and the assumption of "equality" among individuals and across genders[4] (pp. 362–363). Although this paper referenced the then recent completion of a draft of the human genome (p. 347) and commented on the centrality of "human nature" to political thought from Aristotle onwards, its focus was not on genetic contributions to individual outcomes or the heritability of political behaviors.[5]

The study of the genetic underpinnings of political outcomes emerged a few years later, and with some great fanfare, with the publication of a paper in the *American Political Science Review* which argued that "despite the assumptions embedded in political science research," political attitudes have genetic – as well as environmental – underpinnings (Alford, Funk, & Hibbing, 2005, p. 153). The paper was based on analysis of data from twins in the United States, "supplemented" (i.e., with some effort to replicate) with analysis of dataset of twins in Australia. The authors found nontrivial heritability for political attitudes and ideologies, and a modest role for genetics in regard to party affiliation.[6] Although political scientists later took on the *New York Times'* name for their research agenda – "genopolitics" (Biuso, 2008) – the authors initially referred to this work as "empirical biopolitics" (Alford & Hibbing, 2008).

As with genoeconomic research, advocates for empirical biopolitics often refer to earlier behavioral genetics as an initial basis for suspecting that outcomes of interest to political scientists are likely to have a heritable component. Alford, Funk, and Hibbing averred that "political attitudes" have not been a central focus of behavioral genetics research, but asserted, nonetheless, that research on social attitudes and personality traits, for which behavioral genetics suggests strong heritable basis, provide a conceptual rationale; indeed, they propose that political attitudes more closely related to personality traits are more likely to be heritable (2005, p. 157).

While the advocates for genoeconomics noted a variety of "ethical issues" raised by genetics research – many of which were framed as pertaining to methodological challenges – the political scientists interested in genetics acknowledged straightforwardly the "emotional charged" nature of claiming that "attitudes and behaviors are influenced by genetic variables" (Alford et al., 2005, p. 163). They have been careful to instruct their colleagues that "genes do not work in isolation" and "gene-culture interaction is the key to understanding the source of political attitudes and behaviors" (2005, p. 163). Statements that explain and put clear limits on the scope of genetic influence may be critical to the acceptance of this research within the field. In a later review article, two of the authors predict that genopolitics will "flourish" only insofar as "political scientists become increasingly aware that biology does not equate with either universalism or determinism" (Alford & Hibbing, 2008, p. 185).

The authors were certainly correct in anticipating that their 2005 paper – the first twin study published in a political science journal[7] – would be provocative, and in multiple ways. First, it served as a first step in an emerging research agenda, which has included efforts to adapt standard research methods in political science to study heritability (Smith & Hatemi, 2013), enthusiastic mini-symposia and reviews (Alford & Hibbing, 2008; Hatemi, Dawes, Frost-Keller, Settle, & Verhulst, 2011; McDermott & Monroe, 2009), and empirical research aimed at identifying genes that predict political attitudes and behaviors, which now includes candidate gene studies (Fowler & Dawes, 2008) and GWAS (Hatemi et al., 2011). As with genoeconomics, issues regarding adequately powered samples, false positives in studies of gene-environment interaction, and failures to replicate results are ongoing concerns (Chabris et al., 2012; Hatemi et al., 2011).

Second, and in contrast to genoeconomics, the genopolitics agenda has been the subject of both strongly argued and pointed methodological critiques. Advocates of genopolitics contend that "remarkably, in just a few short years, political scientists have far surpassed the original behavioral genetics studies that explored political traits" (Hatemi et al., 2011, p. 80). Additionally, they seek to defuse concerns that genopolitics will lead to biologically reductionist or even eugenic policy regimes: "policies that focus exclusively on social factors have created as much pain and suffering as genetically focused policies" (Hatemi & McDermott, 2011, p. 326). However, attacks on genopolitics have centered primarily on its methodologies, finding fault in the conceptualization of "political phenotypes" (Shultziner, 2013; c.f., Verhulst & Hatemi, 2013) and mocking the genopolitical research agenda more broadly, as an "exercise in naive statistics" (Charney & English, 2013, p. 393). The candidate gene study of voter turnout (Fowler & Dawes, 2008) has been particularly controversial, in part because the authors were unable to replicate one of their main findings in re: the effects of the MAOA gene (Fowler & Dawes, 2013). In their rejoinder to the critique of their study, Fowler and Dawes (2013) make the point that their defense is not of their particular study or of candidate gene approaches but of the "bright future" of "genopolitics" itself as a way of "understanding of the role biology plays in politics" (p. 372).

Sociogenomics

In contrast to its sister social science disciplines, there was never any question that sociology's engagement with contemporary molecular genetics would generate contention. As early as 1907, sociologists were writing about the tensions between sociological and biological explanations for behavior, noting that "the sociologists in the main deem it their duty to deny that there is any necessary connection between social and biological struggles" (Ward, 1907, p. 290). Debate about whether sociology should engage with genetic concepts or methods date back to a heated exchange, in 1967, about the possibility and desirability of "advancement of a theory" that would encompass "the interaction between genetic and social processes" (Eckland, 1967, p. 173). Commenters were quick to critique Eckland's interpretation of evidence in making his claim, especially in regard to his borrowings from other disciplines (Anderson, 1967; Beals, 1967). One writer vividly contended that as to the integration of social and genetic explanations for human traits such as intelligence "profit for sociology lies in balking at every step of the way" (Anderson, 1967, p. 999). Publication of *The Bell Curve* only exacerbated these tensions, despite more thoughtful work along the way (Jencks, 1980). In subsequent years, the possibility of integrative theory and research emerged from time to time. For example, in a reflective essay on the history and future of the discipline, Homans writes that "The most interesting question turns out not to be that of the place of genetics versus that of learning in human behavior, but rather of how the two interact" (1986, p. xxviii). How the two interact was the forefront issue in the research of scholars such as Richard Udry. Udry's work (e.g., 1995) incorporated biology into the sociological investigation of gender, most controversially in his *American Sociological Review* article on "the biological limits of gender construction" (2000), and his reply (Udry, 2001) to the strongly critical comments on his work (e.g., Risman, 2001). Nonetheless, at the turn of the century, the president of the American Sociological Association publicly lamented that "Most sociologists are woefully ignorant of even the most elementary precepts of biological science. If we think about biology at all, it is usually in terms of discredited eugenic arguments and crude evolutionary theorizing long since discarded in the natural sciences" (Massey, 2002, p. 1).[8]

Sociological interest in genetics was heightened by the advent of the HGP, and the related Ethical, Legal, and Social Implications (ELSI) program, which funded research on the consequences of genetic research.[9] Many social scientists were critical of the initial focus of the ELSI program, which assumed a stark division between science and society, as if genetics existed in a temporal and spatial place independent of society (cf. Clarke, Shim, Shostak, & Nelson, 2009; Reardon, 2001; Rose, 2006). Much of the critical work in sociology has been powerfully shaped by the critique of genetic information embedded in the geneticization thesis (Lippman, 1991) and prominent concerns that biological explanations would exist in a zero−sum relationship with sociological explanations (Duster, 2003, but see especially Duster, 2006). The consequences of genetic research for scientific and public understandings of racial categories has been an ongoing concern in the field, with controversies about whether race is "socially constructed" playing out in the pages of prominent journals (Fujimura et al., 2014; Morning, 2014; Shiao, Bode, Beyer, & Selvig, 2012).

Consequently, many sociologists have posited genetics as a threat to be examined, if not countered and debunked, in their research. By the time that the HGP announced the completion of a draft of the genome, sociology had a particularly strong record of empirical research that took genetic concepts, techniques, and social implications as its focus (for a review see Freese & Shostak, 2009). It is commonplace for sociologists to introduce their genetics-oriented work with an explicit acknowledgment of this decades long tension between the biology and sociology; for example, a 2009 paper on "genetics and social inquiry" in the *Annual Review of Sociology* observed that "some sociologists see nothing so opposed to the spirit of their craft as genetics. Deterministic genetic explanations have long served as textbook staples for illustrating what a sociological imagination is *not*" (Freese & Shostak, 2009, p. 108, emphasis added).

Despite these tensions and tendencies, a small group of sociologists have developed a research agenda centered on "gene-environment interaction" that seeks to explain differences in individual outcomes of longstanding interest to sociology (Freese, 2008). An early twins study that exemplifies this agenda sought to identify "social influences," such as parental background, family structure, and sociodemographic characteristics, on whether children realize their genetic potential for intellectual development (Guo & Stearns, 2002). As with similarly "pioneering" articles in economics and political science, the authors used behavioral genetics research as a rationale for their focus on heritability. However, in contrast to the framing of genomics research agendas in economics and political science, the authors emphasized that genetic information could help highlight not the heritability of traits, but the function of effects of the social environment. Similarly, in keeping with sociology's jurisdictional focus on the social environment, this paper concluded that "our work lends further support to public policies that aim at improving the social environments of disadvantaged children" (Guo & Stearns, 2002, p. 906).

As with economics and political science, sociologists have moved from twin studies to candidate gene and GWAS analyses. Sociologists have conducted candidate gene studies on diverse outcomes, including sexual initiation and partnering (Daw & Guo, 2011; Guo, Roettger, & Cai, 2008; Guo, Roettger, & Shih, 2007), educational attainment (Shanahan et al., 2008), delinquency (Guo et al., 2008), smoking and alcohol consumption (Boardman, Blalock, & Pampel, 2010; Daw et al., 2013). Many of these studies have drawn on data from the National Study of Adolescent Health (Add Health), which was among the first longitudinal cohort studies in the social sciences to collect genetic data from participants.[10] In recent years, other prominent cohort studies, including the Wisconsin Longitudinal Study and the Fragile Families and Child Wellbeing Study have also begun to collect genetic data.

Unique among social scientists using genetic information in their research, many genetically engaged sociologists publish not only in prominent sociology and public health journals, but also in genetics journals, including *Biodemography and Social Biology* (Conley, Rauscher, & Siegal, 2013), *Human Genetics* (Guo et al., 2007), the *Journal of Human Genetics* (Conley et al., 2014), the *European Journal of Human Genetics* (Guo et al., 2008), and *Twin Research and Human Genetics* (Shanahan et al., 2007); unsurprisingly, these papers tend to focus more straightforwardly on the social consequences of genetic variation for individual outcomes. Some sociologists now identify as "socio-genomicists" (Conley, 2014). That said, sociologists working with genetic data and techniques tend to emphasize the importance of the social environment in understanding genetic influences.

A somewhat different framing of the relationship between genetics and sociology highlights the possibility that genetic information to advance sociology as a field and protect its jurisdiction (Conley et al., 2014; Freese, 2008). The call for papers for a special issue of the *American Journal of Sociology* focused on "genetics and social structure" invited submissions that

> use genetics or information about heritability *to illuminate the structure and operation of social organization and/or social processes* … tak[ing] advantage of the opportunities afforded by genetic information to better explicate complex social processes or institutions and, thereby, *advance sociological theory and research design* (AJS, 2006, p. 351, emphasis added).

The special issue was, by intention of the editors, a "big tent" (Bearman, 2008), including papers using genetic information with methods from behavioral genetics (Rogers et al., 2008), historical institutional analyses (Shostak, Conrad, & Horwitz, 2008), and SNP-specific approaches (e.g., Shanahan et al., 2008). Although there was some controversy about the special issue (Ledger, 2009; Shea, 2009), two papers published in the special issue won awards from the American Sociological Association the following year (Morning, 2008; Pescosolido et al., 2008), providing some traction for the notion that there is a "distinctly sociological" project that can be advanced by deploying genetic information (Bearman, 2008, p. x). Such a project need not depend on analysis of heritable mutations. A paper published a few years later in *Demography* demonstrated that non-heritable de novo gene mutations may serve as a mechanism linking socio-demographic changes and the increasing prevalence of diseases such as autism (Liu, Zerubavel, & Bearman, 2010).

Moreover, in contrast to their colleagues in economics and political science, sociologists have not limited their research agenda to advancing their own field. Rather, they contend that the life sciences need sociological expertise in order to conceptualize, measure, and assess the effects of the social environment (Perrin & Lee, 2007). In a powerful reframing of the import of the HGP for sociology, Pescosolido argues that insofar as "the environment is a black box to those outside of social science" (Pescosolido, 2006, p. 191), in an era of research on gene-environment interaction, genetics needs sociology to advance its goals:

> Thus, an IOM committee targeting the synergy issue ended by asking, "How should social environments be conceptualized and measured?… Which aspects of the social environment should be included and at what levels of analysis?… How do we consider present influences and those that have accumulated over the life course?" (National Academy of Sciences, 2005b) (Pescosolido, 2006, p. 192).

She notes that ironically, the "the success of 'pure' biomedical science" has provided new urgency to research that looks up from the microscope to focus on the environment" (Pescosolido, 2006, p. 191). Similarly, sociologists contend that "developments in genetics have only served to underscore the importance of social context," especially given the emergence of epigenetics (Shanahan, Bauldry, & Freeman, 2010). A recent paper in the *Annual Review of Sociology* provided a "critical introduction" to environmental epigenetics, contending that sociologists have an essential role to play in the development of this research (Landecker & Panofsky, 2013).

Sociologists who do research on health outcomes, many of whom now work in the emerging interdisciplinary field of population health, have played a prominent role in the development of this research agenda. Here too, their focus has been on developing robust models of the environment as a determinant of individual and population health. In the special issue of the *American Journal of Public Health* dedicated to this topic, sociologists argued that "actually thinking about the environment" in regard to health requires consideration of how environments change over the life course. Lived environments are more than "little Petri dishes" but rather include dynamic processes unfolding across time and place (Bearman, 2013). From this perspective, understanding the environment in gene-environment interaction requires "a multilevel, multidomain, longitudinal framework that accounts for upstream processes influencing health outcomes" (Boardman, Daw, & Freese, 2013). Further, social scientists emphasize "the potentially important role that characteristics of intermediate levels of social organization, such as neighborhoods, schools, and the workplace, have to play" (Boardman et al., 2013). Disciplinary knowledge about the multi-level and processual character of institutions, as well as sociological research design (Fletcher & Conley, 2013), then, provides sociologists with the conceptual and empirical tools for specifying what the environment is, and when and where it matters for the molecular.

THEORIZING THE SOCIAL ENVIRONMENT IN GENE-ENVIRONMENT INTERACTION

As medical sociologist David Williams has noted, in the United States, ones ZIP code affects health more strongly than does ones genetic code (2014). This statement carries two senses of the environment: first, the ZIP code itself, which often proxies for neighborhood in empirical research, and second, the United States as the sort of institutional environment where neighborhood effects are particularly strong. In this section, we sketch medical sociology's current theorization of the environment, from neighborhood-effects studies that bridge into urban sociology, to institutional studies that bridge into cultural sociology and political sociology. Our aim is to clarify how the medical sociology of gene-environment interaction theorizes what the social environment is (Perrin & Lee, 2007), as well as what the social environment does (Shanahan & Hofer, 2005). We note that Nancy Krieger's ecosocial theory (2011) offers a helpful way of integrating the multiple levels, populations, and historical periods that compose the lived social environment. The central concept in ecosocial theory is embodiment: the process whereby people living in a particular place during a specific historical time incorporate their multilevel ecology.

Medical sociology is helpful in the analysis of these comparative-historically specific ecologies. As such, we may be at last witnessing movement beyond stale nature–nurture debates into an era where the opposition of the biological and the social is succeeded by research on the mutual constitution of the biological and the social (Freese, Li, & Wade, 2003; Landecker & Panofsky, 2013; Phillips & Shonkoff, 2000).[11] This makes theorization of the social environment of pressing importance (Bearman, 2013).

Current conceptualizations of the social environment evolve from residualist taxonomies that define as environmental all those things not defined as genetic. Guo et al. (2008) provide a prominent example of the residualist approach, implicitly conceptualizing the environment as everything that comes after conception: "Although DNA sequences are determined at conception and do not change except through mutation, their effects are, with rare exceptions, not deterministic because their expressions are subject to environmental influences immediately after conception" (545). For Guo et al., the social part of the environment is formal institutions of social control (viz., the state and the schools), and informal institutions of social control such as family disruption and peer influence.[12] In their analysis, the social environment becomes a switch that activates or de-activates the behavioral expression of genetic propensity. This residualism is similar to earlier work by Eckland (1967), who defined the environment as "not only … the social milieu but [also] a host of prenatal or molecular factors between the embryonic cells" (177).

Environments are Institutions

A more thorough sociological theorization of the environment identifies how the social phenomena that exist over and above the individuals that compose the social matter for various kinds of inequalities. If one is uncomfortable with "inequality" one can use "dispersion" in its place. These patterns of social relations that shape the distribution of social things can be called institutions, which might interact with genes for at least three reasons.

First, institutions – the "rules of the game" – stratify (Bourdieu, 1983, 1996, 1998). Institutions are crucial for organizing social relations, and for sorting and ranking people into social hierarchies.[13] As people are sorted, institutions determine the kinds of rewards that accrue to different ranks. New research on social stratification provides an example: it is increasingly clear that social class can helpfully be conceptualized in occupational terms, such that instead of one or two or three "big classes," we observe a graded set of "micro-classes" that shape patterns of social mobility (Weeden & Grusky, 2005). Institutions (such as licensing regulations) cement the "occupational closure" that is crucial for income determination (Weeden, 2002). Research on income inequality, much of it using the exceptional data provided by the Luxembourg Income Study, shows that institutions (the welfare state, centralized wage bargaining, and other factors) are the most important determinant of cross-national variation and over-time change in income inequality (Alderson & Nielsen, 2002). Research on poverty also shows that it is largely a function of institutional arrangements that vary dramatically across the rich democracies and influence not only the rate, but also the depth, of poverty (Brady, 2008).

Second, institutions not only influence the extent and kind of social stratification in society, they also condition the operation of the social determinants of health (Boardman et al., 2013). For example, the welfare state – itself a complex of citizenship rights (Marshall, 1950) – provides resources to citizens that may make other kinds of resources less necessary for preventing illness and ensuring good health. One fairly direct effect of the welfare state on health would be the de-commodification of health care. In places where cash is necessary to purchase health care, we would anticipate that income would be a more important determinant of the part of health that is caused by health care (research shows that in the rich democracies, this proportion is small (Woolf & Aron, 2013)). Since societies vary greatly in the extent to which they de-commodify health care, income as a social determinant of health should vary systematically across national institutional arrangements.

Just as it can reduce the importance of material resources for health-enhancing behavior, the social environment can also raise the costs of health-harming behavior. Boardman (2009) shows that in states (social environments) that tax tobacco at a higher rate, people with a genetic predisposition to smoke do so at a lower frequency than they do in states where tobacco taxes are lower. This is a case of the social environment as a set of material (dis-)incentives. Smoking also responds to social incentives that changed across birth cohorts in the US after the release of the surgeon general's report (Boardman et al., 2010).

Third, institutions shape social networks by (a) setting the distribution of people who have various socially relevant traits (e.g., educational attainment, occupation, citizenship; on education see Boardman et al. (2014)), (b) creating the social foci (Feld, 1981; Small, 2009) for the creation and maintenance of ties, and (c) cementing systems of meaning (culture) into organizations, policies, and laws. We view work on how institutions create social networks and moderate their effects as a forefront area of research that could connect the macro-sociological to the micro-epigenetic (Bearman, 2013; Pescosolido, 2006).

Neighborhoods, Families, and Schools

To the extent that institutional arrangements have been incorporated into gene-environment interaction research, they have been measured as attributes of neighborhoods, families and schools. Such research conceptualizes the neighborhood, family or school environment as creating stress or providing resources to individuals, who suffer or benefit differentially depending on their individual genetic propensities.

Neighborhood effects research draws on insights from urban sociology and social demography to explain individual health as a function of characteristics of neighborhoods. The social environment is captured in such studies by the availability of foods (Diez Roux, & Mair, 2010), segregation (Gehlert et al., 2008), and collective efficacy (Sampson, Morenoff, & Earls, 1999). Very little of this rich theorizing has made its way into gene-environment interaction research. Exceptions include Boardman, Barnes, Wilson, Evans, and de Leon (2012), who examine cognitive functioning across low- to high-disorder neighborhoods, and find that genetic propensities matter more where disorder is lower. They infer this is consistent with a "social push" model of gene-environment interaction, which holds that genotype-phenotype linkage is stronger where the social environment exerts less stress on the body.

The major contrast to the "social push" view of gene-environment interaction is the differential-susceptibility model, which holds that genes immunize some people against social forces, while making other people more vulnerable to those same forces. For example, there is evidence that smoking rates in schools create social pressures to which some are more vulnerable than others depending on genotype; viz., short alleles on 5HTTLPR (Daw et al., 2013). Likewise, as rates of alcohol consumption among school peers increase, the influence of the genetic propensity for alcohol consumption also increases (Guo et al., 2009). Also, there is evidence that low family SES exacerbates the genetic propensity to experience depression (Mezuk, Myers, & Kendler, 2013).

Nations, States, and Cultures

Receiving less attention from gene-environment researchers than these meso-level institutions are macro-level institutions that differentiate nation-states. Comparative research from political sociology and political science has developed an array of conceptual approaches to understanding cross-national differences in institutional arrangements (Kenworthy, 2004; Pontusson, 2005). Before delving into this conceptual catalogue, we note that the bounded-ness of society is of course itself a thorny problem. Some of the most innovative on-going research problematizes "the national" itself as a natural boundary of institutions, thereby surpassing the "methodological nationalism" that characterizes much research from the social and population sciences (Bonikowski, 2010; Wimmer & Glick-Schiller, 2002). Such work is of course directly related to theoretical issues in epidemiology surrounding the very definition of "population" (Krieger, 2011). Nevertheless, attending to national institutions in theorizing the environment may have utility, given (1) the large national health disadvantage of the US population relative to the populations of other nations, and (2) the predominance of national-level policy in the kinds of institutions we consider. We note that a forefront area of research is supra-, sub-, and non-national populations and policy (Beckfield, 2009; Lynch, 2009).

Institutional arrangements that differentiate the United States from other rich democracies that have better overall mortality profiles include social welfare benefits in the areas of health, pension, and unemployment insurance (both generosity and coverage vary systematically and can be rigorously measured), collective bargaining institutions, political incorporation, incarceration, and cultural configurations. Very little empirical work has been done to explore gene-environment interactions with these parts of the social environment (but see Conley & Springer, 2001 for an application of welfare-state theory to infant mortality and low birthweight). Guo and Adkins (2008) and Guo (2006) provide exceptions, in developing some of the implications for large-scale social closure (a mass-elite pattern of rule by the few) for the expression of genetic propensities. Also, Guo and Stearns (2002) show that parental unemployment reduces the ability of children to achieve their intellectual potential, implying that labor market institutions may well constitute part of the social environment that interacts with genetic propensity.

One striking characteristic of welfare-state research is that the mechanisms, or processes that are theorized to connect political institutions and population health, are rarely tested in a way that would allow for a role of gene-environment interaction. Typically, if mechanisms are addressed at all, appeal is made to secondary research on hierarchy stress (the argument being that institutions that flatten hierarchies reduce stress and elevate health, presumably by reducing cardiovascular disease; see Hall & Lamont, 2009). The material resources organized and distributed by the welfare state could interact with gene expression involved in the experience of stress, but this has not been tested.

Nations are symbolic as well as material contexts, and the resources distributed by institutions identified above only become meaningful in the context of culture (Perrin & Lee, 2007). Cultural sociology is currently developing a rich array of concepts that disaggregate "culture" into specific structures of meaning (Smith, 1998), including narratives, scripts, identity, symbolic boundaries, and repertoires (Lamont & Small, 2008; Smith, 1998). For example, symbolic boundaries are constituted very differently among the French than they are among Americans (Lamont, 1992), raising the possibility that symbolic variation across environments could moderate genetic effects (to the extent that feelings of belonging and exclusion relate to epigenetic processes). Meaning structures are notoriously difficult to measure, though perhaps no more so than other aspects of the social environment, and Lizardo and Skiles (2012) have made a start on a cultural approach to gene-environment interaction by showing that cultural omnivorousness comes from genes and occupational environments.

Crucially, national social policies do not develop independently from the science of gene-environment interaction. Public understanding of genetic research has the potential to influence social policy across domains, which raises pressing questions about how public opinion responds to genetic research and itself forms part of the social environment (Freese & Shostak, 2009). Aside from one study that found that beliefs about genetic causes of individual differences is associated with support for different kinds of genetically oriented public policies (Shostak, Freese, Link, & Phelan, 2009), there is much we still need to learn about the interaction between public opinion about genetics and the development of specific science policy and public policy regimes.

CONCLUSIONS

We conclude by noting currents and contradictions. First, several currents in the scientific infrastructure for gene-environment research will influence the development of the field in the near term. The SSGAC – the leading organization coordinating interdisciplinary genetic association studies of social science outcomes – identifies 71 cohorts as sources for their ongoing initiatives. Most of these studies come from biomedical research, and can be expected to have a relatively impoverished range of environmental measures. There are also a number of prominent longitudinal cohort studies in the social sciences – the Fragile Families and Child Wellbeing Study, Add Health, the Health and Retirement Study, and Wisconsin Longitudinal Study, primary among them – that are incorporating genetic data. These studies have been central to the development of key environmental measures within the social sciences, and offer a potentially robust basis for the development of a distinctively social scientific approach to research on gene-environment interaction. Scholars in the developing field of population health research have been at the leading edge of using such data to bring multiple determinants of health into the analysis of health disparities in the United States (Adler & Stewart, 2010; Berkman, Kawachi, & Glymour, 2014). As such, there are two mostly distinct initiatives underway, within the social sciences, to develop research on gene-environment interaction. These efforts, the knowledge that they produce, media attention they generate, and research infrastructures and networks they develop are important foci for ongoing analytic attention.

Second, current work on epigenetics – molecular processes such as methylation and histone modification that modify gene expression – raises contradictions that both warrant and complicate the possibility of collaboration between social scientists and molecular biologists. Indeed, proponents suggest that epigenetics may rework the relationships between the life sciences, the humanities, and the social sciences:

> [U]nderstanding the epigenetics consequences of social exposures stands not only to revolutionize medicine but also to transform social sciences and humanities as well. Epigenetics could serve as a bridge between the social sciences and the biological sciences, allowing a truly integrated understanding of human health and behavior. (McGowan & Szyf, 2010, p. 71)

Epigenetics asks "how environments come into the body and modulate the genome," thereby shifting the focus of prior research which considered rather how "genetic variation modifies the sensitivity of the body to the environment" (Landecker & Panofsky, 2013, p. 349). As scholarly observers of the contemporary life sciences have noted, "It is almost ironic that the deeper biologists delve into the human body and the more fine-grained and molecularised their analyses of the body become, the less they are able to ignore the many ties that link the individual body and its molecules to the spatio-temporal contexts within which it dwells" (Niewöhner, 2011, p. 290).

However, even as it offers a means of conceptualizing how socio-economic differences – as manifest in differences in sociomaterial environments – become embodied, epigenetics may simultaneously render those very socioeconomic differences as a "fuzzy background" for the bioactive molecules – the methyl groups, histones, etc. – which emerge as the "real" actors shaping human bodies, and their vulnerabilities (Landecker, 2011, p. 184). This molecularization of the social serves the interests of molecular biologists, who, having failed to deliver on many of the promises of the HGP, now conduct boundary work to incorporate molecular understandings of "the environment" into the ever-expanding domain of the (epi)genetic (Shostak, 2013). At the same time, it raises profound epistemological and political issues about the molecularization of the social determinants of health (Shostak & Moinester, 2015). These tensions may themselves serve as a warrant for increasing collaborative engagement between social scientists and life scientists, perhaps especially in regard to the policy implications of epigenetics (Pickersgill, Niewöhner, Müller, Martin, & Cunningham-Burley, 2013). Certainly, they highlight the critical importance of sociological theorization of the environment across levels of analysis, especially in regard to inequality and health.

NOTES

1. To be clear, this chapter does not comprehensively review the social sciences' engagements with genetics. Rather, our focus is on how a specific subset of researchers who have made a case for taking up the conceptual frameworks and techniques of genetic science to further the goals of the social sciences.
2. Retrieved from http://www.ssgac.org/. Accessed on November 30, 2014.
3. Biopolitics, as theorized by Michel Foucault, has served as the jumping off point for an extensive literature in the sociology of science and the sociology of health and illness, including contemporary work on genetics (e.g., Rose, 2006). However, this is not the agenda being promulgated by Masters in 2001.
4. Masters' arguments regarding gender relied on research that was outdated at the time of its publication. For a critical history of the search for a biological basis for gender, see Richardson (2013).
5. In fact, the author argued that despite the significant attention garnered by the Human Genome Project, "behavioral biology" was the site for the "most astounding advances" and the appropriate focus of engagement for political science (p. 363).
6. The attitude measures in the U.S. sample come from the from the Wilson–Patterson inventory, which is used to assess relative liberalism versus conservatism.

7. As they note, behavioral geneticists had done research on the heritability of conservatism, albeit construed more as a psychological trait than a political ideology (Alford et al., 2005, p. 157).

8. A very few sociologists position their work in relationship to evolutionary theory (e.g., Hopcroft & Martin, 2014). In the main, sociological research that uses empirical data to evaluate evolutionary theory either refutes or complicates its claims (Freese & Powell, 1999, 2001).

9. The literature on the ethical, legal, and social implications of genetics is vast and a review is beyond the scope of this paper. A compendium of research publications from projects funded by the National Human Genome Research Institute's Ethical, Legal, and Social Implications (ELSI) program is available at http://www.genome.gov/17515635 (accessed on September 17, 2014).

10. The importance of the Add Health study for genetic research in the social sciences is difficult to overstate. A list of genetic focused publications based on the Add Health data is available at http://www.cpc.unc.edu/projects/addhealth/publications?form.b_start=0&form.searchabletext=genetics&form.sort_on=ryat&form.actions.search=Search (accessed on September 17, 2014).

Documentation of the candidate gene data collected in Wave IV of the study is available at URL: http://www.cpc.unc.edu/projects/addhealth/data/guides/DNA_documentation.pdf (accessed September 17, 2014). A memorial tribute to J. Richard Udry, one of the designers of Add Health, notes that "It is likely the largest survey in the world (and perhaps the only one) to contain an embedded behavior genetic sample of more than 3,000 pairs of siblings with varying biological resemblance, coupled with high quality molecular genetic data on the entire sample, each based on a probability sampling design that is nationally representative." At URL: https://sociology.unc.edu/features/dr.-j.-richard-udry-kenan-distinguished-professor-of-maternal-and-child-health-and-sociology-remembered (accessed on September 17, 2014).

11. Guo and Adkins (2008) offer a helpful introduction to methods used in genetic research, Guo, Elder, Cai, and Hamilton (2009) demonstrate techniques for incorporating DNA collection into social surveys, and Wagner, Li, Liu, and Guo (2013) discuss natural-experiment data for identification of gene−environment interactions.

12. For the distinction between "the environment" broadly defined, versus the social context (see Shanahan et al. (2010, p. 35)).

13. In fact, Levi Martin argues that Bourdieu's fields analysis may be "completed, not contravened" in by research that looks at fields in terms of interinstitutional relations (Martin, 2003, p. 26).

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