

Under the Influence of Genetics: How Transdisciplinarity Leads Us to Rethink Social Pathways to Illness¹

Bernice A. Pescosolido, Brea L. Perry, J. Scott Long, and
Jack K. Martin
Indiana University, Bloomington

John I. Nurnberger, Jr.
*Indiana University–
Purdue University Indianapolis*

Victor Hesselbrock
University of Connecticut

This article describes both sociological and genetic theories of illness causation and derives propositions expected under each and under a transdisciplinary theoretical frame. The authors draw propositions from three theories—fundamental causes, social stress processes, and social safety net theories—and tailor hypotheses to the case of alcohol dependence. Analyses of a later wave of the Collaborative Study on the Genetics of Alcoholism reveal a complex interplay of the *GABRA2* gene with social structural factors to produce cases meeting DSM/ICD diagnoses. Only modest evidence suggests that genetic influence works through social conditions and experiences. Further, women are largely unaffected in their risk for alcohol dependence by allele status at this candidate gene; family support attenuates genetic influence; and childhood deprivation exacerbates genetic predispositions. These findings highlight the essential intradisciplinary tension in the role of proximal and distal influences in social processes and point to the promise of focusing directly on dynamic, networked sequences that produce different pathways to health and illness.

INTRODUCTION

Historically, problems with alcohol have attracted the attention of both social and biological scientists. While some contend that the idea of the

¹ The Collaborative Study on the Genetics of Alcoholism (COGA) includes nine different centers where data collection, analysis, and storage take place. This national collaborative study is supported by an NIH grant (U10AA008401) from the National Institute on Alcohol Abuse and Alcoholism and the National Institute on Drug Abuse.

heritability of alcoholism is over a century old (Murray and Stabenau 1982), others maintain that it dates to ancient times (Hesselbrock et al. 2001). Medical studies that searched for genetic influences through family, adoption, and twin studies (e.g., Hesselbrock 1995) provided confirmatory evidence for leading candidates. Sociologists and other social scientists studying alcoholism have depended on social influence models (e.g., social learning theory; White, Bates, and Johnson 1991) and theories on the strength of normative structures to mitigate the development of alcohol dependence (Roman 1981). Ironically, as genetic studies picked up in the 1980s, sociological attention lagged, likely because of a combination of courtesy stigma within the discipline, a political climate that discouraged investigation of social factors in illness, and the medicalization of alcohol problems under a growing biomedical dominance in research (Roman 1982).

Perhaps there is no better marker of that dominance than the Human Genome Project, completed ahead of schedule and under budget in 2003, which ushered in the “genomic era” (Bonham, Warshauer-Baker, and Collins 2005). Yet the irony underlying one of the most significant medical science achievements of the 20th century lies in its accompanying conclusion: the environment—from chemical toxin exposure to national structures of inequality—plays a critical role, particularly in more complex health and illness problems. Indeed, calls for research agendas that target “cells to society” (Abrams 1999) or “neurons to neighborhoods” (Shonkoff and Phillips 2000) have been issued by the most prestigious arbiters of medical science in American society (Pescosolido 2006a).

Notions of epigenetic modification and gene-environment interactions theorize the intermingling and mutual influence of biological/genetic and social factors to produce complex health problems. From a sociological perspective, these new directions in the medical sciences agenda raise questions about the power of social structure and the role of social processes. Does the inclusion of genetics dampen, heighten, or otherwise change the influence of social factors in the onset of medical problems? Do genetic theories of the development of individual problems, defined as medical in nature, alter sociological theories of illness and disease?

Here, we attempt to offer some preliminary insight into these questions by focusing on one case, alcoholism; social structure shapes the definition, determinants, and outcomes of drinking patterns, as well as the medical response to these problems. Similarly, as noted above, genetic predispositions, as well as physiological processes, have been implicated in the

Direct correspondence to Bernice Pescosolido, Department of Sociology, Indiana University, 1022 East Third Street, Bloomington, Indiana 47405-7103. E-mail: pescosol@indiana.edu

probability that casual drinking will translate into abuse or dependence as a result of biochemical variations in the way that different groups react to alcohol (e.g., Asians or women; Goodwin 1991).

Using data from one of the premier multisite medical studies of alcoholism, the Collaborative Study of the Genetics of Alcoholism (COGA), we consider both sociological and genetic views of disease. We develop and test a set of direct and interactive hypotheses about the influence of social and genetic factors in the hope of setting sociological challenges for the transdisciplinary agenda.

THEORETICAL BACKGROUND: CLASSIC AND CONTEMPORARY THEORIES OF ILLNESS AND DISEASE

The Call for Transdisciplinarity

In *New Horizons in Health*, a report from the National Research Council of the National Academy of Sciences, one listed priority for this “new era of research” is understanding “environmentally induced genetic expression and its connection to positive and negative health outcomes” (Singer and Ryff 2001, pp. 17, 3). Debates about the primacy of genetics and biology versus society and culture have been declared “scientifically obsolete,” replaced instead by a view of “their inseparability and complementarity,” and characterized by “deliberate efforts to forge ongoing interaction among scientists” (Shonkoff and Phillips 2000, pp. 6, 41, 14; Hernandez and Blazer 2006; see also Guo and Stearns 2002; Horwitz et al. 2003).

At the heart of these arguments lies the notion that social and genetic factors are interconnected. To date, three basic theoretical approaches have been offered: (1) Genetic factors shape social processes; that is, genetic inheritance influences social achievement via an influence on educational attainment and human capital acquisition (Guo and Stearns 2002) or shapes the social safety net via a tendency to develop affiliations such as marriage (the *social mediators* option; Dick et al. 2006a). (2) Injurious social factors “trigger” or “suppress” gene expression; that is, poverty or other stressful life circumstances “turn on” particular disease genes (the *social trigger/suppressor* option; Singer and Ryff 2001). (3) Genes attenuate or exacerbate the effects of social stressors and negative life events; that is, sensitivity to child abuse is reduced among children with protective genotypes (Caspi et al. 2002), or family disruptions are more likely to result in psychopathology among children with high-risk genotypes (the *genetic attenuation/exacerbation* option; Silberg et al. 2001). Although not necessarily analytically distinct, these alternative perspectives constitute the basic, transdisciplinary theoretical approaches underlying the contem-

porary push to integrate social and genetic influences on illness and disease.

The Case of Alcohol

Early and often, alcoholism has been singled out as a particularly rich case for integrative investigation (e.g., Bearman and Brueckner 2002; Guo 2006). Indeed, the precursors of alcoholism, such as stress, socialization, and coping styles, have been described as being driven by broad social structural influences as well as linked to gene expression and to multiple pathophysiological systems (e.g., Singer and Ryff 2001, p. 130). As a result, some argue that behavioral disorders, psychopathology, and antisocial behavior represent the prime candidates and leading edge for environmental-genetic studies (Merikangas and Avenevoli 2000).

Figure 1 presents the general theoretical framework, derived from the discussion above, that guides our analyses. This figure posits direct effects of the three streams of sociological theory, genetic models, and a basic gene-environment interaction. We develop propositions and then narrow to hypotheses matching available operational measures.

THE SOCIOLOGICAL VIEW

We believe that the essence of the sociological contribution can best be captured through a conceptualization of three traditions that represent persistent themes in sociological inquiry: the theory of fundamental causes, stress process theory, and social safety net theories.

The Theory of Fundamental Causes

Social inequality, and its impact on health, illness, and disease, represents one of the most enduring concerns of health-focused social science, as well as of social medicine, social work, and public health (Robert and House 2000). Indeed, the frequently offered observation that each of the founders of sociology focused, to one extent or another, on the social gradient of life and death as a window into general social processes and power differentials is hardly novel (Lutfey and Freese 2005; Pescosolido, McLeod, and Avison 2007). This realization notwithstanding, a recently elaborated lifestyle-based approach focused on individuals (emphasizing health-related choices made by individual actors relative to diet, exercise, smoking, etc.), has come to dominate public and professional discourse, often pushing social factors to the background.

Link and Phelan (1995) reminded sociologists of the complexities of the

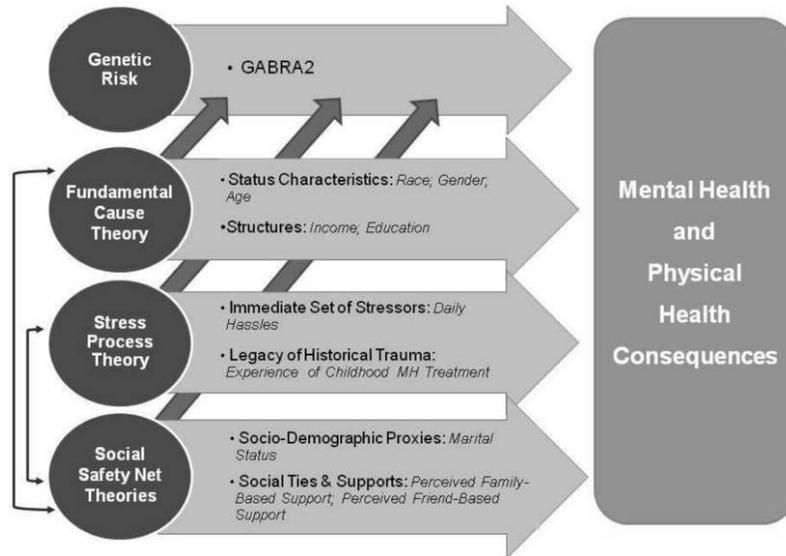


FIG. 1.—Sociogenetic model (simplified)

relationship between social inequalities and the onset of illness and disease. The theory of fundamental causes questioned the dominant focus of risk-factor epidemiology on proximate causes. Rather, they argued that the larger social context shapes access to economic resources, cultural norms, and social meanings that underlie lifestyle and biological mechanisms. At each point in time and place, social context determines links between social structure and disease, and as those larger conditions change, so do the mechanisms that connect inequality and life chances (see Lutfey and Freese [2005] for an elaboration). Consequently, this basic sociological theory posits that

PROPOSITION 1.—*Factors locating individuals on the social fault lines of society that denote power differentials will shape negative health, illness, and disease outcomes.*

With regard to the theory of fundamental causes, McLeod and Non-nemaker (1999) clarify that the components of social stratification (resources and power) are made up of structures (e.g., poverty, segregation) and status characteristics (race, gender, and age). We focus on five sociodemographic characteristics that directly measure or tap into social inequality:

HYPOTHESIS 1.—*Income, education, race, gender, and age will be associated with a diagnosis of alcohol dependence.*

The Stress Process

Stress theories focus on social experiences in terms of discrete events (e.g., divorce, abuse), pressures (e.g., job stress, marital discord) and enduring social conditions (e.g., economic strains, discrimination). As Wheaton (1999a) notes, this conceptualization lays out both the *rooting* (social origins, contingencies, and types of stress) and the *routing* (sequences and coping responses) of stress. Over time, stress research has included a focus on life events, daily hassles, nonevents, traumas, and ecological stressors, which are conditions of “threat, demand or structure constraint” that call into question the “operating integrity of the organism” (Wheaton 1999a, pp. 281, 278). Eventually, this led to a two-way classification defined by whether the stress is discrete or continuous and by the social level from which the stress emanates—micro, meso, or macro (Wheaton 1999b). What is key, according to Pearlin (1999), is that the stress process connects individuals to their inner selves (i.e., identity), to the rhythms of their daily lives, and to the larger social contexts in which they are embedded. In sum, the theory of the stress process holds that

PROPOSITION 2.—*Social stressors, whether chronic or episodic, or current or past, influence negative health, illness, and disease outcomes.*

Theories of the stress process focus on the health-related impacts of both the immediate set of stressful social experiences and the legacy of historical traumas. To that end, we hypothesize that

HYPOTHESIS 2.—*Experiences of childhood maltreatment and daily hassles will be positively associated with a diagnosis of alcohol dependence.*

Social Safety Net Theories

The role of network-based resources available from family, friends, organizations, and even geographical areas in the social epidemiology of health, illness, and disease has become a mainstay of sociological and behavioral research (Pescosolido and Levy 2002). Tracing their roots back to Durkheim ([1897] 1951), social support theories that came into vogue in the 1970s tended to focus on the power of social structure to help defend against social, biological, or genetic insults to individuals (Meyers, Lindenthal, and Pepper 1975). While the presence of strong social ties has been found to mitigate negative health outcomes, social ties have also been shown to be the vectors of morbidity and mortality (e.g., tuberculosis [Klov Dahl, Graviss, and Musser 2002], obesity [Christakis and Fowler 2007], and suicide [Pescosolido and Georgianna 1989]).

The difference in traditions (e.g., social support, social network, or social capital perspectives) found in the various historical and subfield roots led to divergent theoretical conceptualizations (Pescosolido 2006b). On the

one hand, according to Turner (1999), social support comprises support network resources, supportive behavior, and perceived social support. In this social psychology-based approach, social networks represent one component of social support, and the focus is on the sustaining qualities of social relationships (Haines, Beggs, and Hurlburt 2002). Support may be perceived (i.e., one may believe that love, caring, and assistance are potentially available from others) or received (i.e., one may actually use others for caring, assistance, appraisal [Thoits 1995]; on the activated networks in the structural tradition, see Knoke [1990]). On the other hand, the more structurally oriented social network approach sees social networks as the web of social relations that offer opportunities through which resources such as social support may or may not be provided and invoked (Faber and Wasserman 2001). Despite conceptual differences, we expect that

PROPOSITION 3.—*Social relationships will be associated with health, illness, and disease. Specifically, negatives ties will predispose individuals to health problems, while positive ties will protect individuals.*

Traditionally, social supports that make up the social safety net have included both sociodemographics considered to be proxies for the existence of positive ties and direct measures of the actual and perceived availability of support from families and individuals in the community. These ties provide the kinds of emotional and instrumental assistance that have been hypothesized to decrease the occurrence of negative stressors or to lessen their impact:

HYPOTHESIS 3.—*Being married and having greater support from family and friends will be negatively associated with a diagnosis of alcohol dependence.*

THE GENETIC VIEW

Simple Heritability Arguments

Genetic research is primarily inductive in nature, searching for “candidate genes” (e.g., the serotonin transporter gene *5-HTT* is implicated in depression; Caspi et al. 2003). Initially, genetic linkage studies involved searching pedigrees in families that display high prevalence of a disorder or have remained relatively genetically isolated.² In recent years, associ-

² The Old Order Amish are a classic example. This unique community was considered ideal for data mining, because Old Order Amish allow neither conversion nor marriage to non-group-members. Genetic isolation both limits the possible genes involved and amplifies their effects, making them easier to detect. Analyses did isolate a candidate gene for bipolar depression, a disorder with a polygenic mode of inheritance. However, even as this finding continues to be cited, replicating it in other family lines has proven problematic (Ginns et al. 1996; Levin 2005).

ation methods have located some single genes responsible for the linkage peaks in these chromosomal areas. They allow the interrogation of virtually every gene in the human genome at once. A basic proposition of genetic research posits that

PROPOSITION 4.—*Genetic profiles, particularly candidate genes or suspicious gene clusters, discovered through an inductive process will be associated with negative health, disease, and illness outcomes.*

Research on alcohol dependence implicates a dozen or more genes, each with only a modest effect on phenotype (Dick and Foroud 2003). The most promising candidate gene implicated in alcohol dependence, as documented in earlier analyses of the COGA data, is *GABRA2*, located on chromosome 4 (Edenberg et al. 2004; Whitfield et al. 2004). The protein product of the *GABRA2* gene is the alpha 2 subunit of the GABA-A receptor protein. Single nucleotide variants in the *GABRA2* gene are associated with a modest elevated risk of alcohol dependence (Hesselbrock 1995; Reich et al. 1998; Edenberg et al. 2004). The gene variants thus far identified are not associated with differences in the amino acid composition of the protein but are presumed to participate in the regulation of the amount of protein produced.

GABA is the major inhibitory neurotransmitter in the mammalian brain. Changes in GABA receptor regulation may be associated with decreased effectiveness of inhibitory processes in the brain, which may in turn be associated with central nervous system hyperexcitability and various behavioral disorders such as substance abuse (Begleiter and Porjesz 2000). GABA-A receptors appear to mediate some of the subjective effects of alcohol and other drugs, including benzodiazepines (Koob 2004). More specifically, individuals with certain variants of *GABRA2* have a low level of response (LR) to the intoxicating effects of alcohol (Pierucci-Lagha et al. 2005), a trait that has been linked to the development of alcohol dependence. LR individuals must consume more alcohol to achieve anxiolysis, or anxiety-reducing sedation, which may initiate a cycle of increasing tolerance and consumption. At least two other GABA receptor genes, *GABRA1* and *GABRG3* (Dick and Foroud 2003) have been associated with alcohol dependence.

We focus on *GABRA2* for two reasons: (1) since previous COGA analyses found a predisposing effect of *GABRA2*, doing so sets up the possibility of exploring gene \times environment interactions, and (2) not using the same paradigm of data analysis that established this effect, we are able to provide information on the robustness of *GABRA2*'s influence. This GABA-related gene variant is quite prevalent. About 55%–60% of the general population carries one or more copies of the risk allele, and about 33%–35% carries two (dbSNP). The relative risk associated with homozygosity is about 1.2–1.4 (Dick et al. 2006a), and the amount of

genetic variance explained by *GABRA2* variation is estimated to be 6%–12% (assuming an overall relative risk due to genetic factors at 2.0). This type of estimate will be more precise when large samples of cases and controls are genotyped at this locus, which may be expected as part of genome-wide association studies now in progress (Nurnberger et al. 2004). Thus, following from proposition 4, we set a replicating hypothesis:

HYPOTHESIS 4.—*GABRA2 will be associated with a modest but significant increase in risk for a diagnosis of alcohol dependence.*

THE CROSS-CUTTING VIEW

Epigenetic Modification: Genes-Environment Interactions

Many of the most commonly cited behavioral-genetic findings are based on an earlier traditional model that pits genetic and social or environmental contributions to disease against one another. This approach is, in part, a function of the previously popular methodology of twin and adoption studies, utilized to support notions of the importance of heredity (Collins et al. 2000). For some time now, behavioral geneticists have supplemented this simplistic additive model with a more complex multifactorial model of disease. The contemporary view suggests that numerous genes and environmental stimuli interact, are mediated in the brain, and change over the life course to produce any of a set of multiple potential outcomes (Singer and Ryff 2001). Most heritable medical problems are assumed to be attributable to varying degrees of genetic and environmental influence, to be encoded by not one gene but a set of polygenes, and to demonstrate genetic heterogeneity (i.e., many genetic paths to the same outcome, such as hypertension). Diseases once thought to operate under a clear and simple recessive genetic model are now presumed to be shaped by polygenic complexities (e.g., cystic fibrosis, muscular dystrophy) and susceptible to environmental influence (e.g., fragile X syndrome), resulting in significant variation in severity, treatment response, and prognosis (Hamer 2002). Thus, contemporary transdisciplinary theory proposes a more nuanced process:

PROPOSITION 5.—*Genetic predispositions and environmental context, including social structures and social experiences, exist in a complex and mutually dependent relationship, interacting to influence health, illness, and disease outcomes.*

Regarding the *GABRA2* gene's effects on alcohol dependence, interactions with age (around 20) and marital status (married) have been identified. A high-risk genotype on *GABRA2* is expressed more strongly in currently married individuals and among those in stable marriages (Dick et al. 2006b). However, *GABRA2* is associated with symptoms of childhood

conduct disorder, suggesting that the gene may shape patterns of uninhibited behavior that manifest in unique ways at different developmental stages. Dick et al. (2006b) speculate that the overall rate of alcohol dependence in individuals who are unstably married or never married is sufficiently high that the risk associated with *GABRA2* is undetectable.

In addition, gender often conditions social opportunities and the effect of genes implicated in behavioral disorders (Martin, Blum, and Roman 1989; Horwitz et al. 2003). Gene-environment interactions have also been suggested in analyses regarding childhood abuse (Caspi et al. 2002) and social supports (Fox et al. 2005). Finally, the issue of race has consistently presented problems for geneticists (Bonham et al. 2005) and, to some extent, for sociologists, since the effects of race on drinking are also conditioned by gender; for example, black women, perhaps more than any group, are likely to abstain from alcohol use or drink only infrequently (Martin 2000).

We do not offer a firm set of nonadditive hypotheses. Rather, we empirically explore the general idea that the effects of the sociological influences will vary by the level of the candidate gene. Stressors, inequality, and supports will be examined to see if their effects differ depending on *GABRA2* allele status:

HYPOTHESIS 5.—Factors that reflect disadvantaged social status will produce greater genetic effects, while those that tap advantaged social positions will lessen genetic influence.

Endogeneity: Gene-Environment Correlations

The identification of gene-environment interactions is further complicated by the social mediator option discussed earlier. In this theoretical approach, also referred to in genetics research as “gene-environment correlations” and in sociological/social science language as “the endogeneity problem,” genes are theorized to shape the degree to which individuals are exposed to certain social conditions, how they interpret or react to those experiences, and the extent to which social conditions affect health and other outcomes (Rutter 1997). For example, the *GABRA2* gene is associated with marital status, and not simply as a reflection of the effects of alcohol dependence on marriage and divorce (Guo and Stearns 2002; Dick et al. 2006a). Individuals with and without alcohol dependence who carry the high-risk genotype are less likely to be currently married, to ever have been married, or to be involved in a stable marriage, suggesting that *GABRA2* may shape personality characteristics that influence the likelihood of marriage and divorce. In addition to interacting with social variables to produce health outcomes, genetic heritability may be working *through* social structural conditions, making it difficult to tease out genetic

and social influences. Within data limits, we explore Dick et al.'s (2006a) alternative conceptualization, examining gene-environment correlations and endogeneity issues, which essentially posit a classic mediating model whereby genetic factors shape *both* social structural conditions and illness.

HYPOTHESIS 6.—*The effects of social factors will be associated with and attenuated in the presence of genetic influence.*

Limitations

Both genetic and sociological theories are more nuanced and interconnected than figure 1 allows. Our purpose is to explore how genetic and sociological factors meet (in essence illustrating if, where, and how they interact) as a platform for understanding the implications for sociological theory and the transdisciplinary agenda. Given these unexplored complexities, the aims of the COGA study, and the methodological approaches used in medical studies that do not match traditional social science designs, a more conservative approach and parsimonious modeling seems judicious.

DATA, MEASURES, AND METHODS

Sample

Our data come from COGA, a study funded by the National Institute on Alcohol Abuse and Alcoholism (NIAAA) and designed to identify and map predisposing and protective genes for diagnosis of alcohol dependence and related maladaptive patterns of drinking. Data collection took place at nine venues and in two phases. An initial assessment was conducted between 1989 and 1999, and a follow-up assessment was conducted between 1997 and 2004 (Edenberg et al. 2004). Since the measures of stress and support used here were not collected until phase 2, we limit our analyses accordingly. As such, our analyses do not simply replicate earlier studies.

COGA utilizes a case-control methodology that relies on a complex availability-based family selection strategy that collected data from three groups of subjects (Agarwal and Seitz 2001). Two groups of families, referred to as stage-1 or stage-2 families, included persons diagnosed with alcohol dependence who were systematically recruited from consecutive admissions to both inpatient and outpatient alcohol treatment facilities. Stage-1 families had a focal respondent (FR) who met criteria for alcohol dependence and who had at least two first-degree relatives living within a 150-mile radius of the COGA catchment area. Stage-1 FRs and their biological relatives over age 6 who agreed to participate completed a

structured psychiatric interview, provided psychiatric information on other family members, and completed a battery of standardized personality trait measures. Potential stage-1 FRs were ineligible to participate if they were intravenous-drug users, had a life-threatening illness unrelated to alcohol use, did not speak English, or identified as HIV positive. Stage-1 families in which the FR had two or more first-degree relatives who also met criteria for a diagnosis of alcoholism were designated as stage-2 families. In these families, all first-, second-, and third-degree relatives who agreed to participate completed the battery of stage-1 assessments and provided blood samples for biochemical analysis and the extraction of DNA.

A third group of families, designated as community controls, were selected from dental clinics, driver's license bureaus, health maintenance organizations, church congregations, and large corporations. All control families had two parents and at least three biological children over the age of 14. All family members over the age of 6 were evaluated using stage-2 protocol. Control FRs were deemed ineligible if they had a life-threatening illness, had a history of serious head injury or neurological disease, did not speak English, or were known to be HIV positive.

Informed consent was obtained from all adult subjects, and minor children provided informed assent and parental consent. A certificate of confidentiality was also provided by the NIAAA. All subjects received financial compensation for participation.

At the completion of the phase-2 follow-up assessment, these selection procedures yielded a sample of 10,330 subjects. We eliminated the children and adolescents ($N = 2,537$). Among adults, we excluded those on whom we did not have genetic information ($N = 4,853$) as well as those with missing data on other study variables ($N = 424$). This yielded a final sample of 2,516 adult subjects from 502 families, with an average of 5.0 respondents per family.

Given the nonrandom selection of the alcohol-dependent cases and the community controls, the final sample could have problems of selection bias. COGA's highly selected sample of families with alcoholic pedigrees raises concerns about generalizability. While there are methods to adjust for selection bias (Winship and Mare 1992), they cannot be addressed with the data at hand. As an alternative, we construct different subsamples to explore the robustness of our findings by manipulating the alcohol-dependent and nondependent "treatment" groups. We reestimated all models after omitting alcohol-dependent FRs from the sample ($N = 2,367$) and again using only control families ($N = 828$). See table 1 for descriptive statistics on the COGA sample.

TABLE 1
DESCRIPTIVE STATISTICS ON STUDY VARIABLES, COGA ($N = 2,516$)

| Variable | Mean | SD | Range |
|---|-------|-------|-----------|
| Dependent: | | | |
| Alcohol dependence (1 = dependent; 0 = not) | .35 | .48 | |
| Independent: | | | |
| Genetic risk on <i>GABRA2</i> (1 = at risk; 0 = not) | .34 | .47 | |
| Gender (1 = female; 0 = male) | .56 | .50 | |
| Race (1 = black; 0 = nonblack) | .11 | .31 | |
| Marital status (1 = currently married; 0 = not) | .54 | .50 | |
| Age, in years | 40.30 | 14.60 | 18–84 |
| Education, in years | 13.46 | 2.33 | 4–17 |
| Household income (in \$10,000s) | 5.11 | 4.04 | .05–17.50 |
| Childhood deprivation (1 = yes; 0 = no) | .07 | .26 | |
| Daily hassles (low to high) | 35.17 | 20.30 | 0–120 |
| Family social support (low to high) | 61.77 | 13.01 | 20–80 |
| Friends social support (low to high) | 60.03 | 11.12 | 20–80 |

Variables

Alcohol dependence.—The dependent variable is indexed by the assignment of subjects who concurrently meet DSM-IV (APA 1994) and ICD-10 (WHO 2005) criteria for alcohol dependence or alcoholism. These diagnostic classifications define alcohol dependence as a *long-term pattern* of maladaptive use with clinically significant behavioral, cognitive, and/or physiological impairment. Impairment is assessed by some combination of increasing levels of tolerance; physical withdrawal symptoms; increasing levels of consumption; unsuccessful attempts to control consumption; increasing amounts of time spent obtaining or using alcohol or recovering from drinking; reduction or termination of social, occupational, or recreational activities; and continued use despite knowledge of adverse physical or psychological effects. Alcohol dependence was coded 1 (35% of the subset) if the FR was classified as dependent according to both criteria, 0 otherwise.

We are aware that diagnoses and classification of phenomena such as alcohol dependence are social constructions (Horwitz et al. 2003). Our theoretical, transdisciplinary project requires addressing the concerns of two audiences. We use the dichotomy but attempt to avoid terms such as “being an alcoholic.”

Genetic risk.—*Genetic risk* is indexed by a single item, high risk on the *GABRA2* gene, identified via single nucleotide polymorphism (SNP) genotyping and association analyses as being linked to alcohol dependence

(Reich et al. 1998; Edenberg et al. 2004).³ Increased risk for a clinical diagnosis of alcohol dependence is associated with carrying two copies of the high-risk allele A at the SNP rs279871 on *GABRA2* (Edenberg et al. 2004; Dick et al. 2006a). Participants are classified as having a high-risk genotype (coded 1) if they are homozygous for the A allele, and are coded 0 if they carry one or zero copies of this allele.

Indicators of fundamental causes.—*Gender* is coded 1 for women, 0 for men. *Race* is coded 1 for black, 0 otherwise. Education is coded as a series of dummy variables indicating *less than high school*, *high school*, *less than college*, and *college degree or more*. *Household income* is measured as the log of household income in tens of thousands of dollars. *Age* is measured in years.

Stress process indicators.—The variable for having experienced *deprivation during childhood* is coded 1 if subjects agreed with the question, “When you were 6–13, did you or anyone in your family ever not have enough to eat because your family was poor?” and is 0 otherwise. *Daily hassles* is measured by the 53-item DeLongis daily hassles scale. This measure is composed of items indexing how much of a hassle a particular activity, venue, or person (e.g., work, children, spouse, friends, clients, sex) has been in the last week (Weinberger, Hiner, and Tierney 1987). Response categories range from “none” or “not applicable,” coded 0, to “a great deal,” coded 3. We computed the square root of the sum of all items with missing data, which were coded as 0.⁴

Indicators of social safety net protections.—*Marital status* is coded 1 for currently married, 0 otherwise. *Family social support* and *friends social support*, based on the social support index (Procidano and Heller 1983), use 20 items to indicate perceived support. Sample items include “My family (friends) provide the moral support I need” and “I rely on my family (friends) for emotional support.” Response categories are 1 = generally false, 2 = more false than true, 3 = more true than false, and 4 = generally true. Items are coded so that higher scores indicate more perceived support. Two measures sum all nonmissing items, rescaling to the original range of 20–80.

³ In preliminary analyses, we explored the effects of *CHRM2* and *ADH*. However, we could not replicate significant associations from earlier studies. These empirical findings reinforced our decision to focus solely on *GABRA2*.

⁴ COGA data do not distinguish between “no stress” and “not applicable.” We cleaned these data using social category variables (e.g., marital status) to recode individual responses to “missing.”

Analytic Approach

The effects of *GABRA2* and social factors on alcohol dependence are modeled with a population-average logit model (Fitzmaurice, Laird, and Ware 2004, pp. 297–99; Rabe-Hesketh and Skrondal 2005, pp. 120–24) estimated with StataCorp's (2005) *xtlogit* command. This model adjusts for the lack of independence among observations from having multiple individuals from the same family. Given that our sample is not random, tests of significance should be interpreted cautiously.

A series of models is estimated in table 2. Model 1 includes only *GABRA2* as a predictor of alcohol dependence. Model 2 includes only social variables but does not include *GABRA2*. Model 3 includes both *GABRA2* and the social variables. Because of the nonlinearity of the logit model, the effects of social variables on alcohol dependence can differ by the level of *GABRA2*. Given our fundamental interest in whether the effect of social variables differs by genotype on *GABRA2*, we also ran a series of exploratory models that added a single multiplicative term for *GABRA2* with a social variable (e.g., *GABRA2* × female was added to model 3). A separate model was estimated for each variable. We computed the predicted probability (i.e., marginal probability) of alcohol dependence (Rabe-Hesketh and Skrondal 2005, pp. 120–24) at specific levels of independent variables to examine how the effects of the social variables vary by *GABRA2*.⁵ We also examine gene-environment correlations by testing the association between *GABRA2* and each social variable using a χ^2 test of independence.

While the case-control methods employed in the COGA study are well suited to studies of relatively rare events that are the result of a lengthy developmental process (like alcohol dependence), this design does have limitations regarding generalizability and causality.⁶

RESULTS

Baseline Models

Genetics.—The observed probability of alcohol dependence for individuals with a high-risk genotype, .39, compares to .33 for those at low risk.

⁵ In logit models, Chow-type tests of the equality of coefficients across groups (e.g., testing if the coefficient for *GABRA2* is the same for males as it is for females) are inappropriate since they confound the magnitude of the effect for each group with group differences in residual variation (Allison 1999). Predicted probabilities across groups, however, are unaffected by the confounding of the slope coefficients and variance of the errors (Long 2006).

⁶ Case-control studies are generally unable to address the sequence of events that are presumed to produce the condition of interest and, as such, can only suggest causality based on logical criteria (Coggan, Rose, and Barker 1997).

TABLE 2
POPULATION-AVERAGE LOGISTIC REGRESSION MODELS FOR THE EFFECTS OF
GENOTYPE, FUNDAMENTAL CAUSES, THE STRESS PROCESS, AND SOCIAL SAFETY
NET THEORIES ON ALCOHOL DEPENDENCE, COGA STUDY

| | <i>GABRA2</i> | Social Variables | <i>GABRA2</i> + Social Variables |
|--|------------------|--------------------|-------------------------------------|
| | (1) | (2) | (3) |
| Genotype: | | | |
| High risk on <i>GABRA2</i> | 1.26** (2.55) | | 1.27* (2.41) |
| Fundamental causes: | | | |
| Female | | .25*** (-14.44) | .25*** (-14.43) |
| Black | | .53*** (-3.36) | .51*** (-3.58) |
| Age | | 1.18*** (8.39) | 1.18*** (8.39) |
| Education: ^a | | | |
| High school | | .60*** (-3.38) | .60*** (-3.40) |
| Less than college | | .65** (-2.94) | .64** (-3.01) |
| College degree or more | | .36*** (-6.36) | .36*** (-6.36) |
| Log household income (in \$10,000s) | | .89** (-3.07) | .89** (-2.96) |
| Stress process: | | | |
| Square root of daily hassles | | 1.16*** (5.49) | 1.16*** (5.40) |
| Childhood deprivation | | 1.48* (2.25) | 1.49* (2.26) |
| Social support: | | | |
| Married | | .61*** (-4.42) | .61*** (-4.44) |
| Family social support | | .99*** (-3.62) | .99*** (-3.67) |
| Friends social support | | 1.00 (.90) | 1.00 (.91) |
| Test that all effects are 0: | | | |
| χ^2 | 6.49 | 375.89 | 378.99 |
| <i>df</i> | | 13 | 14 |
| <i>P</i> | .00 | .00 | .00 |

NOTE.—*N* = 2,516. Table presents odds ratios; *z*-values in parentheses.

^a Comparison group is *less than high school*.

* *P* < .05.

** *P* < .01.

*** *P* < .001.

This difference is consistent in direction and magnitude with those found in studies using a different COGA subsample (Dick et al. 2006a). Supporting our hypothesis 4, the robustness of the effect across waves and case mix is reassuring.

As reported in model 1 of table 2, having the high-risk genotype on *GABRA2* increases the odds of being diagnosed with alcohol dependence by 26% (OR = 1.26; $P < .01$). The *GABRA2* effect is essentially unchanged after adding controls for social variables (model 3). Similarly, the effects of social variables on alcohol dependence are nearly identical whether or not genotype is included (compare models 2 and 3). Thus, not only do both genetic and social factors affect medically defined alcohol dependence, but the inclusion of both in the same model specification does not change the effects of each to any great extent, an unexpected result under many transdisciplinary theories (e.g., the social mediators and genetic attenuation/exacerbation options). This same result was found when we restricted our sample to exclude FRs and when we included only control families (results available on request).

Social factors.—As expected under our hypothesis 1, social factors that tap fundamental causes have a significant effect. As income increases, the odds of alcohol dependence decrease (OR = .89; $P < .01$). Being female (OR = .25; $P < .001$) and being black (OR = .51; $P < .001$) both decrease the odds of dependence. However, with age and age² ($\chi^2 = 70.4$; $P < .001$), the predicted probability of dependence increases rapidly from the age of 18 to the mid-forties and then steadily decreases, holding all other variables at their means. A challenge to the theory of fundamental causes lies in the fact that women and African-Americans have lower alcohol dependence. Because these social groups are usually cast as having less social power, this inconsistency presents a key opportunity for future transdisciplinary research. Finally, the odds of alcohol dependence decrease for those with a high school education (OR = .60; $P < .001$), some college (OR = .64; $P < .01$), or a college degree or more (OR = .36; $P < .001$) compared to those with less than a high school education. In sum, social locations associated with greater power generally decrease alcohol dependence, while those with less power increase it. In addition, a clear but curvilinear life course pattern is in evidence, with middle age showing a peak in alcohol dependence.

We also find support for the stress process hypothesis (2), with both current and past stressors at work. The more daily hassles people report the greater the odds (OR = 1.16; $P < .001$) of alcohol dependence; the same relationship holds for those reporting material deprivation in childhood (OR = 1.49; $P < .05$). The social safety net hypothesis (3) is also supported. Being married significantly reduces the odds of alcohol dependence (OR = .61; $P < .001$), as does perceived social support from

family members (OR = .99; $P < .001$). Support from friends does not have a significant effect. Thus, kin-based networks appear to play an important ameliorative role, while current or past stress aggravates problem drinking.

Gene-environment correlations.—We find modest evidence of relationships between genotype and two social variables (hypothesis 6). Among individuals without alcohol dependence, those with a high-risk genotype on *GABRA2* are less likely to be currently married ($\chi^2(1) = 3.98$; $P < .05$) and have lower household incomes ($\chi^2(3) = 9.74$; $P < .05$) than those with the low-risk genotype. Although *GABRA2* may play a small part in shaping social conditions, the gene does not appear to work through the social environment. The effect of *GABRA2* retains the same magnitude, direction, and significance after controlling for social factors.

Gene-environment interaction.—Theories of epigenetic modification and our theoretical frame suggest that the effects of social variables may differ by genotype. The nonlinearity of the logit model allows the effects of social variables to differ by the level of *GABRA2* (Long 1997, pp. 75–76). However, given the potential importance of gene-environment interactions, we also estimated a series of models in which a single multiplicative term is added to model 3 of table 2.⁷

Figure 2 shows predicted probabilities of alcohol dependence from a model that adds a multiplicative term for *GABRA2* and gender to model 3, holding other variables at their means. Women who are at high risk on *GABRA2* and those who are at low risk have the same predicted probability of alcohol dependence (.27). For men, however, those with a low-risk genotype on *GABRA2* have a predicted probability of alcohol dependence of .56, compared to a probability of .67 among those with high genetic risk. We find a similar genotype-by-gender interaction in the subsample without alcohol-dependent FRs and in control families.⁸ Across all analyses, being female means that genetic inheritance is virtually in-

⁷ As mentioned in n. 4 above, standard tests of statistical significance of multiplicative terms are not appropriate for testing group differences. We used predicted probabilities to examine whether the effect of *GABRA2* on alcohol dependence differed by the level of a social variable (e.g., being married or not). Unfortunately, a test for the difference of differences in probabilities is not available. Given the exploratory nature of these analyses, we rely on whether the differences in predicted probabilities are substantively meaningful.

⁸ In the sample without alcohol-dependent FRs, women who are at high risk on *GABRA2* have virtually equal predicted probability of alcohol dependence (.23) to that of low-risk women (.24). For men, those with a low-risk genotype on *GABRA2* have a lower predicted probability of alcohol dependence than high-risk men (.51 and .61, respectively). In the control sample, the predicted probabilities for women at low and high genetic risk are .08 and .12, respectively. Men at low genetic risk have a predicted probability of alcohol dependence of .31, compared to .43 for high-risk men.

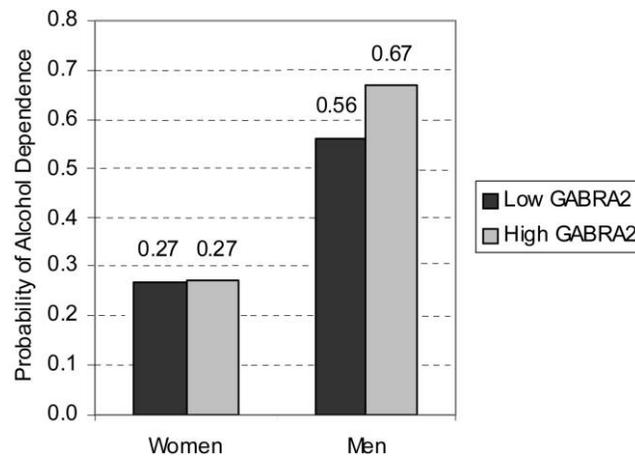


FIG. 2.—Predicted probabilities for alcohol dependence by gender and genetic risk, COGA study ($N = 2,516$).

operative. Given biophysiological studies suggesting lower tolerance in women, these findings implicate the power of social regulation in curbing genetic predispositions to alcohol dependence (Goodwin 1991).

Figure 3 reveals that genotype has a much larger effect for individuals who experienced childhood deprivation than for those who did not. Among people who experienced deprivation, the predicted probability for those carrying the high-risk genotype is .62, compared to .43 for those at low risk. By contrast, the difference in predicted probabilities is only .43 versus .38 among individuals who were not materially deprived as children. Again, results were similar when using the subsample with alcohol-dependent FRs omitted.⁹ Early stressors may trigger the negative effects of the high-risk *GABRA2* genotype. Poverty has been implicated in the resort to risky behavior and “cheap” coping. Both behaviors suggest that “escapist drinking” (Martin 2000) may likely be a culturally and socially programmed response which, in turn, makes genetic predispositions for individuals from disadvantaged backgrounds more likely to find behavioral expression.

Figure 4 displays the effects of perceived family support by genotype. Differences in the predicted probability of alcohol dependence are larger

⁹ In the subsample without alcohol-dependent FRs, the predicted probability of those at high genetic risk who experienced deprivation is .60, vs. .37 for those at low risk (compared to .37 vs. .33 among individuals not materially deprived). In fact, the inclusion of the alcohol-dependent FRs attenuates the magnitude of the interaction between genotype and childhood deprivation. Too few cases of childhood deprivation in control families prevented reanalysis.

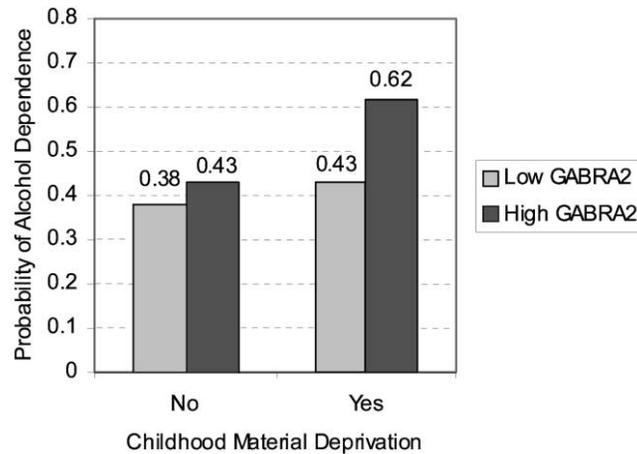


FIG. 3.—Predicted probabilities for alcohol dependence by childhood material deprivation and genetic risk, COGA study ($N = 2,516$).

at low levels of support (where the difference is about .14), suggesting that social support from family members may function as a buffering mechanism among those who are at high risk on *GABRA2*. However, this effect steadily decreases as support increases. The difference in predicted probability at the highest levels of family support is only about .02. Results are similar for the subsample without alcohol-dependent FRs and even more pronounced for control families.¹⁰

In total, empirical evidence suggests interactive findings on social stress and perceived support from family networks in line with social theory. Stress aggravates and network support protects. The support findings are stunning: while individuals reporting no family support have the expected difference in the probability of alcohol dependence given their genetic inheritance, those reporting high levels of support do not. The monotonic decrease in the influence of genetic risk as social support increases implies that social ties can level the risk attributable to genetic inheritance.

¹⁰ In the subsample without FRs, the difference in predicted probabilities of dependence among those at high and low genetic risk is virtually the same (.02, high support; .14, low support). In the control sample, the difference is magnified (.03, high support; .29, low support).

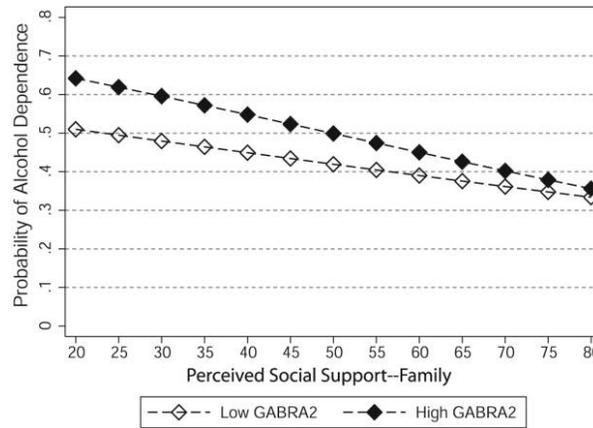


FIG. 4.—Predicted probabilities of alcohol dependence by perceived family support, with other variables held at their means—*GABRA2* interaction, COGA study ($N = 2,516$).

DISCUSSION AND CONCLUSION: THEORETICAL INSIGHTS, SOCIOLOGICAL CAUTIONS, AND FUTURE DIRECTIONS

Pathways and Sequences to Clinical Diagnoses

Drawing data from COGA, we theoretically laid out the set of possible influences between *GABRA2* and indicators of medical sociology's primary frameworks—the theory of fundamental causes, stress process theory, and social safety net theories. Our basic findings replicate previous research. Genes matter. Social structures and experiences matter.

The candidate gene, *GABRA2*, is robust to a different wave of data with different case mixes, offering the same modest increase in the risk of alcohol dependence (about 6%) seen across medical studies. Of course, we explore only a fraction of the variance related to GABA receptor structure. GABA-related variance is, in turn, only one aspect of genetic variance related to alcohol dependence.¹¹ Further, variables tapping into societal fault lines of inequality (e.g., income, education, race, and gender), the experience of stress (e.g., childhood material deprivation, daily hassles), and the presence of a social safety net (e.g., marital status, family-based social support) offer evidence for sociological hypotheses. Of course, we also explore only a fraction of the variance related to social structures and processes.

¹¹ Despite the strength of the social variables, it would be unwise to conclude that social factors predominate over genetics. We examine just one of the many genes implicated in alcohol dependence. Current polygenic theory allows us to go no further. Other candidate genes implicated in alcohol dependence may confer risk via different physiological mechanisms.

Importantly, our analyses offer provocative findings, both for the transdisciplinary agenda and for sociological theory. Genetic and social effects each change little in the presence of the other. While it would be too strong to say that there is no endogeneity problem, these findings are nonetheless curious, suggesting that the effects of genes and society are not confounded. At least for the individuals in the COGA study, genetic inheritance does not push individuals into material deprivation, stressful situations, or alienation from family. However, both nature and nurture push certain individuals to become dependent on alcohol and to receive a clinical diagnosis.

Other, more challenging, findings demand further theorizing. While the nonlinear models estimated here inherently reveal different effects in different parts of the data space, the introduction of two-way interaction terms indicates that sometimes genetic effects are triggered or suppressed. That is, under the right circumstances, genetics and social influences may play complementary roles in the initiation and maintenance of patterns of alcohol-related behavior.

Genetic predisposition to alcohol dependence on *GABRA2* is operative in men but not in women. Given the same genetic inheritance and similar social circumstances, men are more likely to become dependent on alcohol. It is no secret that drinking, especially in public, is more acceptable for men than women in American society. This greater cultural tolerance sets up American men to engage in a pattern of behavior that leads to “alcohol dependence,” especially for those at high genetic risk. As Bearman and Brueckner (2002, p. 1201) contend, “Genetic expression for alcoholism is impossible in cultures without alcohol.”

Findings also point to the interplay of social and genetic factors under the trigger/suppression option. Social experiences, both positive and negative, affect whether and how genotypes translate into behavioral phenotypes. Specifically, a history of deprivation during childhood may trigger the genetic tendency, reinforcing the power of stress theory and previous transdisciplinary findings (Caspi et al. 2003). And, as Durkheim ([1897] 1951) long ago theorized, the existence of a social safety net—in this case, the perceived availability of family-based social support—counters the influence of negative genetic tendencies. Support from family, apparently even in families that have a history of alcohol dependence, decreases the power of genetic predisposition or, perhaps, the “caseness” of dependence (i.e., recognition and identification as a medical problem).

Critically, the family network, but *not* the friendship network, is at work in alcohol dependence. That is, greater support from family networks decreases problematic drinking behavior, but the influence of friend support is equivocal. Family, friends, and even co-workers are, according to White et al. (1991, p. 177), “powerful agents of social influence” with

regard to drinking, because, “like other acquired human behaviors, [drinking] is learned and usually performed in a social context.” Social networks provide motivation for drinking, prescribe when, why, where, and how much to drink, and reinforce or punish certain drinking behaviors by example, attitude, and behavior (Martin 1990).

Taken together, our findings suggest central theoretical roles for network specificity (tie type or context), homophily, and a dynamics of social selection. Network structures can support drinking as entertainment and as a solution or discourage it as problematic or offensive. Spillover effects of drinking may result in problems in existing networks, and selection may determine whether or not individuals continue their drinking patterns or how some network ties can be reconfigured to fit continued drinking. That is, a person who engages in significant drinking will likely face exclusion from nondrinking “chosen” networks (i.e., those outside the family’s ascribed ties) and will seek out networks more in line with their own drinking preferences, even in the workplace (Trice 1965; Kandel 1985). The cultural context of the support structures, often ignored in network theory in favor of a simple focus on perceived numbers or levels, determines the impact of friendship on drinking, as Sutherland (1955) theorized long ago in the theory of differential association regarding other behaviors defined as deviant. Thus, if a network selection process that produces homophily operates for drinking, as recently documented for eating (Christakis and Fowler 2007), then the structure, content, and dynamics of social ties together predispose individuals toward drinking. Our equivocal findings for friendship networks suggest the power of the content and dynamics of less ascribed ties. Without these variables, the effects of supportive networks may cancel each other out. While some friendship networks support or even demand sobriety, others may encourage social or even heavy drinking. Social network cultures and network dynamics become a central component of an integrative theory of alcohol use and abuse, indeed of *any* human behavior, and may be the most promising multilevel perspective to emerge to date.

In sum, our findings suggest a compelling mechanism underlying these gene-environment interactions. If the *GABRA2* gene is expressed exclusively or more strongly in men, those who have experienced stressful life circumstances (childhood deprivation), and those who perceive no social safety net in the form of a supportive family, then those social circumstances likely encourage individuals to turn to alcohol as a coping mechanism (“escapist” or “instrumental drinking”; Martin et al. 1989). Indeed, perceptual and metabolic effects of alcohol consumption have been shown to alleviate the stress associated with negative life events and circumstances (Pearlin and Radabaugh 1976), with men more frequently using alcohol in this way than women (Nurnberger et al. 2004). Under such

circumstances, and with a high-risk genotype on *GABRA2*, a person may require more alcohol to experience its stress-relieving effects. In turn, this low level of response to the anxiolytic properties of alcohol precipitates the development of heavier consumption and a clinical diagnosis of alcohol dependence (Pierucci-Lagha et al. 2005). Stress and an absence of social support initiate coping behaviors, which set in motion a social process that becomes medically problematic in the face of a genetically inherited propensity to drink excessively. These issues are even more critical for genetic or medical research designed not simply to understand disease, but to develop treatment strategies. If individuals diagnosed and treated for alcohol problems return to social networks in which drinking is a usual social activity, then rehabilitation treatment is not likely to take. In the end, cultural context may be more powerful than medical solutions (Glisson and Hemmelgarn 1998).

Further, while Dick and her colleagues (2006a) suggest that high levels of alcohol dependence among the never-married and the divorced masks the relatively small effect of genotype, we suggest an alternative. We find that *GABRA2* exerts influence among those *most likely* to be diagnosed with alcohol dependence. These interactions may not simply be an artifact of the weak influence of *GABRA2*. Rather, if correct, this epidemiological process represents a true blending of sociological and genetic causes: social conditions shape initial behavior, while genetic predisposition increases the likelihood that this behavior becomes habitual, maladaptive, and constructed as a disorder in contemporary society. Thus, social structure sets in motion a social process of coping, negatively spurred on by genetic predisposition and abetted by an absence of positive family network supports, resulting in a diagnosis of alcohol dependence.

The Challenge to Sociological Theory in Pursuing Complex Pathways

We began by asking if and how the inclusion of genetics might change sociological theories. Our analyses suggest that the disease process is characterized by direct influence of genes and society, complicated by interactions between physiological systems and the multiple levels at which social factors shape health outcomes, from culture and social systems to maladaptive behavior. Social factors operating at three different levels—individual stressors, dyadic and small group interaction, and social structural location—increase the likelihood that drinking behavior triggers a physiological response. In short, while medical sociology's theories work as anticipated, our findings suggest that identifying causal pathways requires an examination of points of intersection between and among sociological and genetic mechanisms. This demands an integrative per-

spective that is dynamic, interdisciplinary, multilevel, and, importantly, intradisciplinary.

The sociological theories examined here are not independent, nor have they ignored each other as they have developed over time. As Pearlin (1999, p. 397) indicates, the stress process is not unconnected to individuals' social and economic statuses. In fact, their consideration makes the stress process model "quintessentially sociological." Furthermore, its buffering hypothesis draws directly from the social support tradition (Pearlin and Aneshensel 1986). McLeod and Nonnemaker (1999) go further to suggest that the reason that status characteristics are linked to mental health is because they define important differences in stress exposure. Finally, resources, like social support, are not equally available to all individuals, but are differentially distributed across groups in society (Lin 2000). In short, sociological theories themselves are nuanced and interconnected. While we earlier noted the limitations in our own theoretical model and in the analytic strategy that the available data allow, the issue for sociological theory that we raise goes far beyond this point.

Essentially, the sociological theories that we laid out differ on the issue of distal versus proximate causes that often overlap with levels of analysis. Emerging research suggests that social and biological factors interact at every level of analysis. The chain metaphor and the distal/proximal distinction (Krieger 1990; Link and Phelan 1995) that dominated the decade-long debate surrounding risk factor epidemiology and fundamental social causes of disease may be counterproductive. Although certain social and individual causes of disease may be fundamental in that they persist in a dynamic system, researchers in any discipline have yet to identify a risk factor with a one-to-one relationship to health outcomes. The degree and even the direction of the impact of any one risk factor is inevitably contingent in part on social and biological conditions at different levels of analysis. Our findings suggest that a consideration of the interplay between social-structural and individual-level mechanisms is necessary to identify even one of many causal pathways to a particular disease or disorder.

Blending sociological theories would suggest, for example, that the influence of the *GABRA2* gene would be even further amplified as men who experience high levels of stress also become socially isolated. While this approach requires attention to the ways in which sociological mechanisms attenuate or exacerbate one another, the task of identifying causal pathways becomes even more complex when physiological response levels are introduced. In the case of the pathway to alcohol dependence examined here, various social and genetic influences seem to converge at the point of individual behavior. We know, for example, that social structure and stressors can increase the likelihood of behavior that suppresses

the immune system (i.e., smoking, drinking, and poor diet), increases exposure to pathogens (not seeking out social support), and determines the course and prognosis of disease and illness (utilizing and complying with health care; Cohen and Williamson 1991). Conversely, genetic factors can influence partnering behavior, including one's tendency to become and remain married or to cohabit, which has important implications for the development of substance abuse and other mental illnesses (Dick et al. 2006a). Finally, those who are available as research subjects in traditionally designed, treatment-based medical studies are already at the end of a social process influenced in part by biology and in part by social networks (Pescosolido, Brooks-Gardner, and Lubell 1998; McAlpine and Boyer 2007).¹²

As our results suggest, the identification of complex causal pathways requires a perspective that bridges multiple levels of analysis, as well as disciplinary traditions in theory and method. Individuals (and the total of their psychological and biological competencies, limitations, tendencies, and predispositions) are embedded in dynamic, social relationships that provide a basis for network structures, upon which communities, social institutions, and cultures are built (Lin and Peek 1999; Pescosolido 2006a). Moreover, because networks have recently been used to describe phenomena at virtually every level of analysis, from the cellular to the organizational, across disciplines as diverse as neurology and public health, they are broadly resonant (Weiner 1998; Wellman and Frank 2001; Pescosolido 2006a). Given that stress and social networks (or support) have been linked in countless studies to various heritable physical and mental health problems and health-related behaviors (Singer and Ryff 2001; Pescosolido and Levy 2002), pursuing a dynamic, network-structured approach to theory and modeling of sequence pathways to illness and disease seems promising.

REFERENCES

- Abrams, David B. 1999. "Applying Transdisciplinary Research Strategies to Understanding and Eliminating Health Disparities." *Health Education and Behavior* 33:515–31.
- Agarwal, Dharam P., and Helmut K. Seitz, eds. 2001. *Alcohol in Health and Disease*. New York: Marcel Dekker.
- Allison, Paul D. 1999. *Logistic Regression Using the SAS System: Theory and Application*. Cary, N.C.: SAS Publishing.

¹² Biomedicine's general reliance on nonrepresentative, clinical samples poses a major problem for the ability to understand the dynamic pathways to illness, treatment, and ultimate outcome. To be sure, genetic epidemiologists such as Collins (Collins et al. 2003) have been aware of these difficulties.

Social Pathways to Illness

- APA (American Psychiatric Association). 1994. *Diagnostic and Statistical Manual of Mental Disorders*, 4th ed. (DSM-IV). Washington, D.C.: APA.
- Bearman, Peter, and Hannah Brueckner. 2002. "Opposite-Sex Twins and Adolescent Same-Sex Attraction." *American Journal of Sociology* 107:1179–1205.
- Begleiter, Henri, and Bernice Porjesz. 2000. "What Is Inherited in the Predisposition to Alcoholism: New Model or More Muddle?" *Alcoholism: Clinical and Experimental Research* 24:247.
- Bonham, Vence L., Esther Warshauer-Baker, and Francis S. Collins. 2005. "Race and Ethnicity in the Genome Era." *American Psychologist* 60:9–15.
- Caspi, Avshalom, et al. 2002. "Role of Genotype in the Cycle of Violence in Maltreated Children." *Science* 297:851–854.
- Caspi, Avshalom, et al. 2003. "Influence of Life Stress on Depression: Moderation by a Polymorphism in the 5-HTT Gene." *Science* 301:386–89.
- Christakis, Nicholas A., and J. H. Fowler. 2007. "The Spread of Obesity in a Large Social Network over 32 Years." *New England Journal of Medicine* 357:370–79.
- Coggan, David, Geoffrey Rose, and David J. P. Barker. 1997. *Epidemiology for the Uninitiated*. London: British Medical Journal Publishing Group.
- Cohen, Sheldon, and Gail M. Williamson. 1991. "Stress and Infectious Disease in Humans." *Psychological Bulletin* 109:5–24.
- Collins, Francis S., et al. 2003. "A Vision for the Future of Genomics Research." *Nature* 422:835–47.
- Collins, W. Andrew, et al. 2000. "Contemporary Research on Parenting: The Case for Nature and Nurture." *American Psychologist* 55:218–32.
- Dick, Danielle M., et al. 2006a. "Marital Status, Alcohol Dependence, and GABRA2: Evidence for Gene-Environment Correlation and Interaction." *Journal of Studies on Alcohol* 67:185–94.
- Dick, Danielle M., et al. 2006b. "The Role of GABRA2 in Risk for Conduct Disorder and Alcohol and Drug Dependence across Developmental Stages." *Behavioral Genetics* 36:577–90.
- Dick, Danielle M., and T. Foroud. 2003. "Candidate Genes for Alcohol Dependence: A Review of Genetic Evidence from Human Studies." *Alcoholism: Clinical and Experimental Research* 7:868–79.
- Durkheim, Émile. (1897) 1951. *Suicide*. New York: Free Press.
- Edenberg, Howard J., et al. 2004. "Variations in GABRA2, Encoding the α -2 Subunit of the GABAA Receptor, Are Associated with Alcohol Dependence and with Brain Oscillations." *American Journal of Human Genetics* 74:705–14.
- Faber, Ashley, and Stanley Wasserman. 2001. "Social Support and Social Networks: Synthesis and Review." Pp. 29–72 in *Social Networks and Health: Advances in Medical Sociology*, edited by Judith A. Levy and Bernice A. Pescosolido. Stamford, Conn.: JAI Press.
- Fitzmaurice, Garrett, Nan Laird, and James Ware. 2004. *Applied Longitudinal Analysis*. New York: Wiley.
- Fox, Andrew S., et al. 2005. "Calling for Help Is Independently Modulated by Brain Systems Underlying Goal-Directed Behavior and Threat Perception." *Proceedings of the National Academy of Science* 102:4176–79.
- Ginns, Edward L., et al. 1996. "A Genome-Wide Search for Chromosomal Loci Linked to Bipolar Affective Disorder in the Old Order Amish." *National Genetic Journal* 12:431–35.
- Glisson, Charles, and Anthony Hemmelgarn. 1998. "The Effects of Organizational Climate and Interorganizational Coordination on the Quality and Outcomes of Children's Service Systems." *Child Abuse and Neglect* 22:401–21.
- Goodwin, Donald. 1991. "The Etiology of Alcoholism." Pp. 598–609 in *Society, Culture, and Drinking Patterns Reexamined*, edited by David Joshua Pittman and Deena White. New Brunswick, N.J.: Rutgers Center for Alcohol Studies.

American Journal of Sociology

- Guo, Guang. 2006. "The Linking of Sociology and Biology." *Social Forces* 85:145–50.
- Guo, Guang, and Elizabeth Stearns. 2002. "The Social Influences on the Realization of Genetic Potential for Intellectual Development." *Social Forces* 80:881–910.
- Haines, Valerie A., John J. Beggs, and Jeanne S. Hurlburt. 2002. "Exploring the Structural Contexts of the Support Process: Social Networks, Social Statuses, Social Support, and Psychological Distress." *Advances in Medical Sociology* 8:271–94.
- Hamer, Dean. 2002. "Rethinking Behavior Genetics." *Science* 298:71–72.
- Hernandez, Lyla M., and Dan G. Blazer. 2006. *Genes, Behavior, and the Social Environment*. Washington, D.C.: National Academies Press.
- Hesselbrock, Victor M. 1995. "The Genetic Epidemiology of Alcoholism." Pp. 17–39 in *The Genetics of Alcoholism*, vol. 1 of *Alcohol and Alcoholism*, edited by H. Begleiter and B. Kissin. New York: Oxford University Press.
- Hesselbrock, Victor M., et al. 2001. "Genetics and Alcoholism: The COGA Project." Pp. 103–24 in *Alcohol in Health and Disease*, edited by Dharam P. Agarwal and Helmut K. Seitz. New York: Marcel Dekker.
- Horwitz, Allan V., et al. 2003. "Rethinking Twins and Environments: Possible Social Sources for Assumed Genetic Influences in Twin Research." *Journal of Health and Social Behavior* 44:111–29.
- Kandel, Denise B. 1985. "On the Processes of Peer Influences in Adolescent Drug Use: A Developmental Perspective." *Advances in Alcohol and Substance Abuse* 4:139–63.
- Klov Dahl, Alden S., Edward A. Graviss, and James M. Musser. 2002. "Infectious Disease Control: Combining Molecular Biological and Network Methods." Pp. 73–100 in *Social Networks and Health*, edited by Judith A. Levy and Bernice A. Pescosolido. New York: JAI/Elsevier Science.
- Knoke, David. 1990. *Political Networks*. New York: Cambridge University Press.
- Koob, George F. 2004. "Allostatic View of Motivation: Implications for Psychopathology." *Nebraska Symposium on Motivation Papers* 50:1–18.
- Krieger, Nancy. 1990. "Racial and Gender Discrimination: Risk Factors for High Blood Pressure?" *Social Science and Medicine* 30:1273–81.
- Levin, Aaron. 2005. "Amish Study Explores Roots of Bipolar Disorder." *Psychiatric News* 40:21–25.
- Lin, Nan. 2000. "Inequality in Social Capital." *Contemporary Sociology* 29:785–95.
- Lin, Nan, and M. K. Peek. 1999. "Social Networks and Mental Health." Pp. 241–58 in *A Handbook for the Study of Mental Health*, edited by Allan V. Horwitz and Teresa L. Scheid. New York: Cambridge University Press.
- Link, Bruce G., and Jo C. Phelan. 1995. "Social Conditions as Fundamental Causes of Disease." Extra issue, *Journal of Health and Social Behavior* 35:80–94.
- Long, J. Scott. *Regression Models for Categorical and Limited Dependent Variables*. Thousand Oaks, Calif.: Sage.
- . 2006. "Group Comparisons Using Predicted Probabilities." Working paper. Indiana University, Department of Sociology.
- Lutfey, Karen E., and Jeremy Freese. 2005. "Toward Some Fundamentals of Fundamental Causality: Socioeconomic Status and Health in the Routine Clinic Visit for Diabetes." *American Journal of Sociology* 110:1326–72.
- Martin, Jack K. 1990. "Jobs, Occupations, and Patterns of Alcohol Consumption: A Review of Literature." Pp. 45–66 in *Alcohol Problem Intervention in the Workplace: Employee Assistance Programs and Strategic Alternatives*, edited by Paul M. Roman. Westport, Conn.: Quorum Books.
- . 2000. "Alcohol Use and Abuse among African-Americans: Inter-group and Intra-group Comparisons." Pp. 58–62 in *Self Destructive Behavior and Devalued Identity*, vol. 4 of *The Encyclopedia of Criminology and Deviant Behavior*, edited by C. E. Faupel and Paul M. Roman. London: Taylor & Francis.
- Martin, Jack K., T. C. Blum, and Paul M. Roman. 1989. "Drinking to Cope and Self-

Social Pathways to Illness

- Medication: Characteristics of Jobs in Relation to Workers' Drinking Behavior." *Organizational Behavior* 13 (1): 55–71.
- McAlpine, Donna, and Carol Boyer. 2007. "Sociological Traditions in the Study of Mental Health Services Utilization." Pp. 355–78 in *Mental Health, Social Mirror*, edited by William R. Avison, Jane D. McLeod, and Bernice A. Pescosolido. New York: Springer.
- McLeod, Jane D., and James M. Nonnemaker. 1999. "Social Stratification and Inequality." Pp. 321–44 in *Handbook of the Sociology of Mental Health*, edited by Carol S. Aneshensel and Jo C. Phelan. New York: Kluwer Academic/Plenum.
- Merikangas, Kathleen R., and Shelli Avenevoli. 2000. "Implications of Genetic Epidemiology for the Prevention of Substance Use Disorders." *Addictive Behavior* 25:807–20.
- Meyers, Jerome K., Jacob J. Lindenthal, and Max P. Pepper. 1975. "Life Events, Social Integration, and Psychiatric Symptomatology." *Health Social Behavior* 16:421–27.
- Murray, R. M., and J. R. Stabenau. 1982. "Genetic Factors in Alcoholism." Pp. 135–46 in *Encyclopedic Handbook of Alcoholism*, edited by E. M. Pattison and E. Kaufmann. New York: Gardner Press.
- Nurnberger, John I., Jr., et al. 2004. "A Family Study of Alcohol Dependence." *Archives of General Psychiatry* 61:1246–56.
- Pearlin, Leonard I. 1999. "The Stress Process Revisited: Reflections on Concepts and Their Interrelationships." Pp. 395–416 in *Handbook of the Sociology of Mental Health*, edited by Carol S. Aneshensel and Jo C. Phelan. New York: Kluwer Academic/Plenum.
- Pearlin, Leonard I., and Carol S. Aneshensel. 1986. "Coping and Social Supports: Their Functions and Applications." Pp. 417–37 in *Applications of Social Science to Clinical Medicine and Health Policy*, edited by D. Mechanic and L. H. Aiken. New Brunswick, N.J.: Rutgers University Press.
- Pearlin, Leonard I., and Clarice W. Radabaugh. 1976. "Economic Strains and the Coping Functions of Alcohol." *American Journal of Sociology* 82:652–63.
- Pescosolido, Bernice A. 2006a. "Of Pride and Prejudice: The Role of Sociology and Social Networks in Integrating the Health Sciences." *Journal of Health and Social Behavior* 47:189–208.
- . 2006b. "Sociology of Social Networks." Pp. 208–17 in *The Handbook of 21st Century Sociology*, edited by Clifton D. Bryant and Dennis L. Peck. Thousand Oaks, Calif.: Sage Publications.
- Pescosolido, Bernice A., Carol Brooks-Gardner, and Keri M. Lubell. 1998. "How People Get into Mental Health Services: Stories of Choice, Coercion and 'Muddling Through' from 'First-Timers.'" *Social Science and Medicine* 46:275–86.
- Pescosolido, Bernice A., and Sharon Georgianna. 1989. "Durkheim, Religion, and Suicide: Toward a Network Theory of Suicide." *American Sociological Review* 54: 33–48.
- Pescosolido, Bernice A., and Judith A. Levy. 2002. "The Role of Social Networks in Health, Illness, Disease and Healing: The Accepting Present, The Forgotten Past, and The Dangerous Potential for a Complacent Future." *Social Networks and Health* 8:3–25.
- Pescosolido, Bernice A., Jane D. McLeod, and William R. Avison. 2007. "Through the Looking Glass: The Fortunes of the Sociology of Mental Health." Pp. 3–32 in *Mental Health, Social Mirror*, edited by William R. Avison, Jane D. McLeod, and Bernice A. Pescosolido. New York: Springer.
- Pierucci-Lagha, Amira, et al. 2005. "GABRA2 Alleles Moderate the Subjective Effects of Alcohol, Which Are Attenuated by Finasteride." *Neuropsychopharmacology* 30: 1193–1203.
- Procidano, Mary E., and Kenneth Heller. 1983. "Measures of Perceived Social Support

American Journal of Sociology

- from Friends and from Family: Three Validation Studies." *American Journal of Community Psychology* 11:1–24.
- Rabe-Hesketh, Sophia, and Anders Skrondal. 2005. *Multilevel and Longitudinal Modeling Using Stata*. College Station, Tex.: Stata Press.
- Reich, Theodore, et al. 1998. "Genome-Wide Search for Genes Affecting the Risk for Alcohol Dependence." *American Journal of Medical Genetics (Neuropsychiatric Genetics)* 81:207–15.
- Robert, Stephanie A., and James S. House. 2000. "Socioeconomic Inequalities in Health: An Enduring Sociological Problem." Pp. 79–97 in *Handbook of Medical Sociology*, edited by Chloe E. Bird, Peter Conrad, and A. M. Fremont. Upper Saddle River, N.J.: Prentice Hall.
- Roman, Paul M. 1981. "From Employee Alcoholism to Employee Assistance: An Analysis of the De-emphasis on Prevention and on Alcoholism Problems in Work-Based Programs." *Journal of Studies on Alcohol* 42:244–72.
- . 1982. "Barriers to the Development of Employee Alcoholism Programs." Pp. 139–77 in *Occupational Alcoholism: A Review of Research Issues*, edited by A. A. Pawlowski. Washington, D.C.: Government Printing Office.
- Rutter, Michael L. 1997. "Nature-Nurture Integration: The Example of Antisocial Behavior." *American Psychologist* 52:390–98.
- Shonkoff, Jack P., and Deborah A. Phillips. 2000. *From Neurons to Neighborhoods: The Science of Early Childhood Development*. Institute of Medicine committee report. Washington D.C.: National Academies Press.
- Silberg, Judy, et al. 2001. "Genetic Moderation of Environmental Risk for Depression and Anxiety in Adolescent Girls." *British Journal of Psychiatry* 179:116–21.
- Singer, Burton, and Carol Ryff. 2001. *New Horizons in Health: An Integrative Approach*. Washington D.C.: National Academies Press.
- StataCorp. 2005. *Stata Statistical Software: Release 9*. College Station, Tex.: StataCorp.
- Sutherland, Edwin Hardin. 1955. *Principles of Criminology*. Philadelphia: Lippincott.
- Thoits, Peggy A. 1995. "Stress, Coping, and Social Support Processes: Where Are We? What Next?" Extra issue, *Journal of Health and Social Behavior* 35:53–79.
- Trice, Harrison M. 1965. "Alcoholic Employees: A Comparison of Psychotic, Neurotic, and 'Normal' Personnel." *Journal of Occupational Medicine* 7:94–98.
- Turner, R. Jay. 1999. "Social Support and Coping." P. 676 in *A Handbook for the Study of Mental Health*, edited by Allan V. Horwitz and Teresa L. Scheid. Cambridge: Cambridge University Press.
- Weinberger, M., S. L. Hiner, and W. M. Tierney. 1987. "In Support of Hassles as a Measure of Stress in Predicting Health Outcomes." *Journal of Behavioral Medicine* 10:19–31.
- Weiner, Herbert. 1998. "Notes on an Evolutionary Medicine." *Psychosomatic Medicine* 60:510–20.
- Wellman, Barry, and K. A. Frank. 2001. "Network Capital in a Multilevel World." Pp. 233–73 in *Social Capital*, edited by Nan Lin, Ronald S. Burt, and K. Cook. Hawthorne, N.Y.: Aldine de Gruyter.
- Wheaton, Blair. 1999a. "The Nature of Stressors." P. 676 in *A Handbook for the Study of Mental Health*, edited by Allan Horwitz and Teresa L. Scheid. Cambridge: Cambridge University Press.
- . 1999b. "Social Stress." Pp. 277–300 in *Handbook of the Sociology of Mental Health*, edited by Carol S. Aneshensel and Jo C. Phelan. New York: Kluwer Academic/Plenum.
- White, Helene Raskin, Marsha E. Bates, and Valerie Johnson. 1991. "Learning to Drink: Familial, Peer, and Media Influences." Pp. 177–97 in *Society, Culture, and Drinking Patterns Reexamined*, edited by David Joshua Pittman and Helene Raskin White. Piscataway, N.J.: Rutgers Center on Alcohol Studies.

Social Pathways to Illness

- Whitfield, John B., et al. 2004. "The Genetics of Alcohol Intake and of Alcohol Dependence." *Alcohol Clinical Experimental Research* 28:1153–60.
- Winship, Christopher, and Robert D. Mare. 1992. "Models for Sample Selection Bias." *Annual Review of Sociology* 18:327–50.
- WHO (World Health Organization). 2005. *International Statistical Classification of Diseases and Health Related Problems (ICD-10)*, 2d ed. Geneva: WHO.