Chapter 14

Epidemiology and Urban Health Research

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1.0. WHAT IS EPIDEMIOLOGY AND WHAT ROLE CAN IT PLAY IN URBAN HEALTH RESEARCH?

"Epidemiology" is derived from the Medieval Latin term "*epidemia*," meaning an epidemic, and reflects the origins of epidemiology as the discipline concerned with tracking and controlling disease epidemics. Modern epidemiology has expanded its scope and many definitions for epidemiology have been suggested, some at odds with one another (Swinton, 2004). Most epidemiologists might characterize their discipline as the study of the distribution of disease and of the causes (or determinants) of that distribution (Lilienfeld, 1978). Congruent with this definition, the American Heritage Dictionary defines epidemiology as "The branch of medicine that deals with the study of the causes, distribution, and control of disease in populations" (American Heritage Dictionary, 2000). Therefore epidemiology provides the empiric tools that inform both medicine and public health and epidemiologic method are critical to the study of disease distribution, cause, and subsequently control.

Broadly speaking, we can think of two principal roles for epidemiology. First is a descriptive role, often referred to as disease surveillance. Here epidemiology helps to describe the frequency of disease, both overall, but also in different groups, including, for example, gender, race/ethnicity, geographic groups, or over time. Description of disease is a critical function epidemiology plays to inform public health policy and practice. For example, the recent documentation of the growing prevalence of obesity throughout the U.S. has fuelled national interest in the obesity epidemic and the development of national and regional initiatives aimed at reducing obesity and associated morbidity (Katz, 2003; Wang, *et al.*, 2002). In local public health departments, epidemiologic surveillance of infectious diseases serves to identify infectious disease outbreaks, a core function of both local and federal public health agencies.

Second, epidemiology plays a critical role in understanding disease etiology, or identifying causes of diseases. Classically, epidemiology has concerned itself with identifying different factors, often called "exposures" or "risk factors" that are associated with categorical disease outcomes. Both observational and experimental methods have been employed to this end. Historic examples of this include the identification of smoking as a risk factor for lung cancer and cardiovascular disease and the absence of folic acid as a risk factor for neonatal neural tube defects. In the context of public health practice, epidemiology contributes methods that aid in the search for causes of infectious disease epidemics. For example, outbreak investigations include both the description of the increase in incidence of a particular disease and also the search for the cause, or of the mechanisms of transmission of a well-known cause, of the same disease. Both these traditional roles of epidemiology have concerned themselves with individual disease expression and with the individual factors (including behaviors or exposures to toxins or other possibly harmful substances) that contribute to the development of disease.

Recently there has been an expansion in the role of epidemiology both in terms of the outcomes as well as with the exposures of interest. In terms of outcomes, epidemiologists have broadened their scope to consider not only disease but also health and well-being. In addition, there has been increasing interest in considering the health of populations, not simply of individuals, and in understanding that population health is not an aggregate of the health of independent individuals, but rather a product of inter-dependent individuals who influence one another's health and disease status (Koopman and Lynch, 1999). In terms of exposures or risk factors, modern epidemiologic thinking has expanded its scope beyond intrinsic individual factors or behaviors to consider factors exogenous to the individual (e.g., socio-economic status), individual inter-connections (e.g., social networks and social supports), and contextual factors that are not characteristics of any one individual (e.g., social capital) (Kaplan, 1999). In broadening its scope to include these factors modern epidemiology has made its task, the description or characterization of states of health and the determinants of those states, considerably more complex than it was a few decades ago. The development of epidemiologic methods (e.g., regression techniques, hierarchical analysis) that can account for increasing analytic complexity both has made it possible to meet the challenges introduced by this broader scope and raised new questions in its own right (Oakes, 2003).

As discussed in many chapters in this book, the study of urban health encompasses a broad range of questions, exploiting, and challenging the epidemiologic armamentarium. In this chapter we will first discuss the different perspectives that have been employed in the epidemiologic literature that explores questions relevant to urban health, second we will consider various aspects of epidemiologic techniques and how they can be applied to questions in urban health, and third we will discuss key challenges facing epidemiology in the study of urban health. We will conclude with directions for epidemiologic inquiry in urban health. We note that we do not here attempt to explain epidemiologic methods, instead referring the reader to standard epidemiologic textbooks for explanation of epidemiologic techniques (Rothman and Greenland, 1998; Gordis, 2000). Instead, we consider how epidemiologic approaches may illuminate questions in urban health research and potentially guide intervention. This chapter draws on our other published work that presents some of the issues discussed here in more detail (we refer the reader to Galea and Vlahov, 2004; Galea, *et al.*, 2005; Galea and Schulz, 2006).

In order to illuminate some of the points being made in this chapter, we will refer throughout to an example that we hope will be illustrative of the role epidemiologic methods can play in urban health research. Recently, there has been growing interest in the possible role that the built environment may play in shaping health (Jackson, 2003). For example, specific features of the built environment including density of development, mix of land uses, scale of streets, aesthetic qualities of place, and connectivity of street networks, may affect physical activity (Handy, *et al.*, 2002). In turn, low levels of physical activity are a well-established risk factor for cardiovascular disease and all-cause mortality in urban areas (Diez-Roux, 2003; Pate, *et al.*, 1995). Other work has shown that a deteriorating built environment is associated with greater incidence of sexually transmitted diseases (Cohen, *et al.*, 2000). Considering the role of the built environment is clearly a priority of studies that consider the relations between living in urban areas and health. Several chapters in this book discuss the multiple potential roles of the built environment in shaping health. Heavily built environments are the hallmarks of many urban areas, and urban residents are in greater contact with the built environment on a daily basis than are non-urban residents. Therefore, if the built environment is a determinant of human health it is likely to play an important role in shaping the health of urban populations. We will consider different aspects of questions related to the urban built environment and health throughout this chapter.

2.0. DIFFERENT PERSPECTIVES ON THE EPIDEMIOLOGIC STUDY OF URBAN HEALTH

The study of urban health thus far has fallen to work in multiple different disciplines, each employing methods that are particular to a specific field. Epidemiologic methods have been employed in some of this work, occasionally in concert with methods from other disciplines. However, in general, we can consider three types of studies that have applied epidemiologic methods to address questions relevant to urban health. These are: studies comparing rural and urban communities, studies comparing cities within countries or across countries, and studies examining intra-urban (e.g., neighborhood) variations in health. We will discuss each of these types of studies briefly highlighting the methodological issues inherent to each type of study.

Until recently, studies that have compared rates and prevalence of morbidity and mortality in urban and rural areas were probably the most common application of epidemiologic techniques to urban health, although these studies have become less common in recent years. Following the two different roles of epidemiology discussed earlier, these urban vs. rural comparisons largely fall in the category of descriptive, or surveillance, epidemiology. These studies typically contrast several urban areas with rural areas in the same country, or consider morbidity and mortality in urban vs. non-urban areas, the latter frequently being defined as all areas that do not meet "urban" criteria. These studies are typically cross-sectional studies, considering both the characteristics of the urban and rural areas and the prevalence of morbidity and mortality rate at one point in time. These studies are best suited to address questions about *whether or not urban areas are characterized by different burden of disease than are non-urban areas.* Such urban-rural or urban-non-urban comparisons may also draw attention to particular features of urban areas that may be associated with health and that merit investigation. However, these studies are limited in their

ability to shed light on what these features may be and on how urban areas may affect the health of the residents within them.

Considering the example introduced earlier about assessing the role of the built environment in shaping health, urban-rural comparisons can shed little light on whether the built environment actually is associated with a particular morbidity. Urban-rural comparisons could be employed to assess if cardiovascular disease is more prevalent in urban verses rural areas (e.g. Keil, *et al.*, 1985). For example, a study could collect data from several urban and non-urban areas and compare cardiovascular disease mortality between the two types of areas. Demonstrating that there is a higher prevalence of cardiovascular disease mortality in urban areas then might alert us to something about the urban context that may predispose urban residents to higher cardiovascular disease than their non-urban counterparts. However, urban-rural comparisons are not able to suggest whether it is the built environment, or other characteristics of urban areas (e.g., air pollution) that are contributing to cardiovascular disease. More sophisticated analyses are needed to attempt to deduce reasons for any observed urban-rural difference in morbidity.

Given these limitations, that different urban-rural comparisons have provided conflicting evidence about the relative burden of disease in urban and non-urban areas is not surprising (Galea and Vlahov, 2004). Changing conditions within cities over time, and differences in living conditions between cities suggest that at best these studies provide a crude snapshot of how the mass of urban living conditions at one point in time may be affecting population health. These studies may be most relevant in areas where urbanization is still proceeding rapidly (e.g., China or India), helping public health officials to predict changing national health profiles as the proportion of the population living in urban areas increases (e.g., Zhao, 1993).

The second type of study that attempts to address how cities affect health involves comparisons of health between cities, either within a country or between countries (e.g., Levine, *et al.*, 1989). Using the city itself as the key unit of analysis, these studies compare different cities in order to reach conclusions about urban characteristics associated with health. Although these studies can play a surveillance role, they also may begin to generate etiologic hypotheses that may explain *why* differences in health and disease exist between urban areas. These studies contribute to the ability to discern features of cities that may promote or harm population health and may suggest practices at the city level that are amenable to intervention that improves population health. These studies are best suited to ask *which characteristics of cities as a whole may be associated with specific health-related outcomes.* Returning to our running example, cross-urban comparisons can test associations between the quality of the built environment and health in cities. Therefore, a study that collects information about the quality of buildings in different cities and then uses statistical testing to determine if there is an association between quality of buildings in a city and the prevalence of sexually transmitted diseases can suggest that the quality of the built environment may influence behavior, or facilitate disease transmission. Urban-urban comparisons also can be used to assess inter-urban differences in health service delivery and to assess the relations between these differences and health outcomes (Rodwin and Gusmano, 2002). Comparisons of health risk factors within three cities in China (Beijing, Shanghai, and Hong Kong) have shown different risk profiles between cities (Fu and Fung, 2004).

However, by considering the city as the unit of analytic interest, these studies implicitly assume that aggregate behaviors or characteristics at the city level are equally important for all residents of those cities. This limits the consideration of

how cities may affect the health of urban residents to an analysis of city-wide characteristics that may, or may not, affect all urban residents equally. In addition, demonstrated cross-sectional disparity in risk factors and morbidity between urban areas may equally be due to some causal difference in the urban context as it may be due to other factors, such as selective migration in specific cities. Epidemiologic methods, including stratification, restriction, or regression modeling can be applied to adjust for such potential confounders. However, even after adjustment for confounding, observed urban-urban disparities may not necessarily reflect a relation between the urban context and individual health. Inference documented through ecologic studies cannot be extended to the individual-level and as such, these studies cannot be used to infer relations between the urban context and the health of individuals (this has been referred to as the "ecologic fallacy"; see Lilienfeld, 1983; Diez-Roux, 2000).

A third group of studies has employed epidemiologic techniques and has contributed to our understanding of how city living may affect health. This group of studies has become more common in the past decade and has frequently included studies of how living in particular urban communities may be associated with health. Most commonly, these studies focus on spatial groupings of individuals (typically conceived as "neighborhoods", although several studies assess the contribution of administrative groupings that are not necessarily meaningful to residents as neighborhoods) and typically consider the role of one's community of residence within an urban area on individual health. *These studies then are suited to assessing questions related to which characteristics of areas within cities may be associated with individual health.* These studies are more suited to considering questions of disease etiology than are any of the two other study designs discussed here. Returning to the example of the built environment, several studies have shown that the quality of neighborhood sidewalks is associated with the likelihood of physical activity among urban residents (Sharpe, *et al.*, 2004; De Bourdeaudhuij, *et al.*, 2003). Intra-urban analyses may thus assess how the quality of buildings in one's neighborhood of residence is associated with individual health behavior or disease status. In addition, and importantly, multi-level analytic techniques can allow the consideration of these associations while taking into account both potential group-level and individual-level confounders. Although this work by and large has thus far been carried out using cross-sectional study designs, recent work has employed other epidemiologic study designs including case-control studies and longitudinal studies to test multi-level hypotheses (Galea, *et al.*, 2003a; Windle, *et al.*, 2004; Sundquist, *et al.*, 2004; Marinacci, *et al.* 2004). These study designs, as discussed later, allow us to avoid problems with reverse causality that are inherent to cross-sectional study designs. However, it is important to note that while these studies contribute important insights about urban conditions and their implications for health they may be difficult to generalize to other cities, or to urban areas more broadly.

3.0. EPIDEMIOLOGY AND URBAN HEALTH

Multiple epidemiologic methods lend themselves to the study of urban health and, as discussed above, different methods may be more applicable to different questions in the field. We discuss here three epidemiologic approaches to questions that may pertain to the study of urban health and then present particular considerations that may influence both the choice of epidemiologic method

employed and the interpretation of results from the studies employing each of these methods.

3.1. Epidemiologic Approaches

A number of epidemiologic approaches can be used to examine urban health issues. Here we present three broad approaches, namely, ecological, contextual, and hierarchical approaches. The purpose of these analyses is to identify factors associated with place (i.e., cities) that can affect the health of urban residents.

Ecologic analyses consider associations between factors at the group or aggregate level. For example, ecologic analyses can consider the association between population density and all-cause mortality rates across cities. Simple correlations can suggest features of cities that co-vary with measures of population health at the city level while more sophisticated techniques such as regression analyses can consider how particular factors co-vary with others while accounting for the contribution of potentially important variables. Ecologic analyses provide an opportunity to document how characteristics of cities are related to population health in the aggregate and have historically been the primary method used in urban-rural and inter-urban comparisons discussed above (e.g., Schouten, *et al.*, 1996; Douste-Blazy, *et al.*, 1988; Hersh, *et al.*, 1992). The primary current use of ecologic analyses in the study of urban health is to generate hypotheses about features of cities that may affect health; in the context of the examples discussed above, urban-rural and urban-urban comparisons typically make use of ecologic analyses. Returning to our running example, ecologic analyses can assess whether availability of park space is associated with the prevalence of cardiovascular disease mortality in city neighborhoods.

However, ecologic analyses, while potentially useful in identifying features of cities that may shape population health, have limited usefulness in determining *how* these characteristics of cities may be associated with individual health. Causal inferences at the individual level cannot be drawn from ecological associations. For example, ecologic observation that show cities with lower availability of park space have higher cardiovascular disease mortality rates say little about the individual use of park space, or individual exercise patterns, and whether there are causal links between access to park space, health behavior, and cardiovascular disease mortality. This inability to draw cross-level inference limits interpretations that can be drawn from ecologic observations. However, ecologic analyses will probably continue to play a role in urban health primarily in hypothesis generation and in suggesting characteristics of cities that may influence population health. Ecologic analyses are not limited to inter-urban comparisons, but can equally generate hypotheses about features of intra-urban units that may shape population health (e.g., neighborhoods, social networks).

Contextual analyses assess how urban living, as a characteristic of the individual, is associated with health. Contextual analyses, together with ecologic analyses, have been most commonly employed in the studies of urban vs. rural (or non-urban) health discussed above. Thus, contextual analyses attribute to the individual a variable that represents whether or not one lives in an urban vs. rural context and then analytic methods, ranging from contingency tables to regression analyses, are applied to determine if an individual's likelihood of having a particular health status (including the presence or absence of disease or morbidity from a particular disease) is higher or lower in urban individuals compared to non-urban individuals. Contextual analyses consider urban as a variable with a fixed effect on

individuals, i.e., that the urban variable has the same effect on all individuals in an analysis. Simple methods can consider the association of the urban variable with health status without controlling for the role of other potentially confounding or modifying variables, while more sophisticated methods (e.g., Mantel-Haenzel adjustment, multiple regression) can assess the role of the urban variable while taking into account other potentially important variables (e.g., gender). Extending the park space analysis discussed above, contextual analyses can attribute to the individual an area-level variable representing urban park space availability and can assess if this variable is associated with individual risk of cardiovascular disease while controlling for potential individual behaviors or characteristics that may confound the relation of interest.

Although relatively common in urban health research, the inferences that can be drawn from contextual analyses about how urban living can affect health are limited. Contextual analyses assume that the import of a given urban characteristics in a given city is the same for all individuals in the analyses. This obscures the fact that some individuals may have more or less *access* to the park pace that is available to everyone. Access to park space may be determined by individual proximity to such space, socio-economic barriers to park space use, or any number of factors that are not accounted for by the attribution of a simple measure of park space availability to all individuals equally in an analysis. Overall urban contextual analyses fail to provide insight into *how* cities may affect health and contextual analyses within cities remain limited to an assessment of a few key variables in isolation. As such, the role of contextual analyses in urban health studies is limited primarily to descriptive summaries of the burden of health in specific urban contexts. While this may be useful in advancing urban health as a topic for investigation or intervention, contextual analyses has limited utility in scientific inquiry that attempt to understand disease etiology.

Relatively new to the study of urban health, multilevel analyses allow the consideration of how characteristics of cities, or of units within cities, contribute to individual health independent of the contribution of other individual and contextual variables. For a full review of the methods behind multilevel analyses we refer the reader to other published work (Diez-Roux, 2001; Langford, *et al.*, 1999). Specific considerations with respect to multilevel urban studies are discussed in the next chapter ("Design and analysis of group (or neighborhood) level urban studies") in this book. In brief, multilevel analyses consider the contribution of variables at multiple levels to the variability in a particular individual-level dependent variable. In its simplest application to urban health, a multilevel analysis uses data from individuals in multiple cities (or from multiple areas within a city) to consider whether city living independently explains inter-individual variability in health status after controlling for other relevant individual characteristics. More useful to the study of urban health however is the consideration of how different *characteristics* of urban living at multiple levels may be associated with health. For example, multilevel analysis can test whether social capital at the city level is associated with individual mental health while controlling for social ties at the neighborhood level and for individual characteristics (Kawachi and Berkman, 2001). In our running example, multilevel analysis can be used to test whether living in neighborhoods characterized by deteriorating buildings is associated with individual behavior or disease outcomes while taking into account individual demographic characteristics.

Multilevel analyses also allow the investigator to consider the possibility that urban living has a different effect on individuals in different urban communities by

introducing random slopes that allow for variable strengths of the association between urban characteristics and health. For example, multilevel analyses may show that the salutary effect of green space is different in different areas of a particular city (Takano, *et al*,. 2002; Tanaka, *et al*,. 1996). Therefore, multilevel methods allow for the analysis of how characteristics of urban living may affect health and how these associations may differ in different urban communities, taking into account factors at other levels that may be important determinants of health. If applied in inter-urban datasets, multilevel methods can assess the role of city-level variables as well as of variables at different levels within cities. These methods hold much promise in urban health research.

3.2. Study Design

The three broad categories of epidemiologic methods discussed here can be applied in a variety of different contexts and in conjunction with multiple study designs. There are several considerations, pertaining both to the particular research questions of interest and to each of the analytic methods discussed here, that merit discussion as we consider the role of epidemiologic methods in urban health.

The methods summarized above may be applied to several study designs. Cross-sectional studies are the basis of most of the existing urban vs. non-urban contextual analyses and also represent the most common study design for multilevel analyses. The ubiquity of cross-sectional study designs primarily reflects the fact that cross-sectional studies are easier and less expensive to design and execute than longitudinal studies. Also, analyses relevant to urban health have tended to rely on publicly available community level indicators to characterize urban and intra-urban areas and as such are constrained by the fact that these data are usually collected at infrequent intervals. Multilevel analytic methods while comfortably developed for cross sectional analyses have been somewhat more complicated for prospective data that involves possible changes at each and across all levels. However, longitudinal study designs are becoming more important to advance hypothesis testing in urban health (e.g., Molnar, *et al.*, 2004). While cross-sectional studies can document associations between characteristics of urban living and health, they cannot provide information about the temporal relations between characteristics of urban areas and the onset of disease, an essential step in causal inference. For example, a cross-sectional multilevel study can establish that living in urban neighborhoods characterized by a deteriorating built environment is *associated* with greater sexual risk behavior (Cohen, *et al.*, 2000), but cannot establish that the urban built environment *causes* riskier behavior. It is equally plausible that persons who engage in risky sexual behavior migrate to neighborhoods where deteriorating buildings are the norm (and are potentially cheaper to live in). Longitudinal studies (or well-designed case control studies that mimic longitudinal studies through careful control selection) are needed to advance thinking about how urban characteristics may cause different health behaviors and outcomes and ultimately to suggest which urban characteristics can fruitfully be subject to intervention. It is also worth noting that new research suggests that longitudinal research that takes into consideration life course perspectives, i.e., how exposures in one's early life may affect subsequent health, (Lawlor, *et al.*, 2003) may have a particular contribution to make in considering the role of urban living in shaping population health.

More challenging, but potentially even more useful, experimental studies that manipulate characteristics of the urban environment in a controlled fashion can

help isolate and establish how features of the urban environment may affect health. Although examples of experimental studies in urban health are uncommon, a few examples have shown promising results. For example, in Chicago, specific housing projects were landscaped while others were not, through a natural experiment, and investigators were able to show that persons living in the upgraded housing projects had improved functioning, fewer episodes of interpersonal violence, and better concentration than persons in the control group (Kuo, 2003). Such studies can convincingly demonstrate the role that particular aspects of the urban environment play in shaping health and, perhaps more importantly, identify avenues for intervention.

Important considerations in selecting a study design are limitations regarding sample size and the statistical power available for multilevel or intra-urban analyses. The size of the analytic sample both at the individual level and at the group level becomes a relevant concern for multi-level designs. Power calculations for multilevel analyses remain limited, but it is clear that in order to carry out meaningful comparisons of the role of group-level variables, sufficient numbers of groups must be included for a particular study, requiring larger study samples and more complex study designs (Hoover, 2002).

3.3. Analytic Considerations

Epidemiologic analyses frequently rest on translating broad concepts into operational variables that can then be analyzed using some of the methods discussed earlier. Although this is true of all quantitative analyses it may be a particularly important issue in urban health studies. In urban health studies variables need to be specified that represent complicated constructs often with varying meaning in different contexts. "Urban", while referred to throughout this chapter as a potential variable of interest, is challenging to define, and definitions vary between countries and between studies (Galea and Vlahov, 2004). This variation limits inter-study comparisons and generalizations. Clear and reproducible definitions of urban may facilitate such comparisons. More saliently, specification of the "exposures" of interest is a critical issue in all quantitative urban health research. Throughout this chapter we have discussed how constructs at multiple levels (e.g., qualities of the built environment, social ties) may be assessed in urban health studies. Several chapters in this book elaborate further about what these constructs are and how they may influence health. Recognizing that the role of specific constructs may be different across urban contexts makes the careful specification of the key exposures of interest critical. Therefore, while we encourage consideration of multiple levels of potential influence in the urban context, we also note that more work needs to be done on appropriate specification of important urban constructs before convincing quantitative work can assess whether these constructs influence health.

Another consideration in thinking about quantitative analyses in urban health pertains to the complexity of urban living as a variable of interest. We discussed earlier how contextual urban vs. non-urban analyses are frequently not replicable, probably reflecting the complexity of each individual urban setting and the inability of a single "urban" variable to summarize multiple relevant dimensions. However, summarizing all the variables of interest in the urban context can be daunting and fully representing the key relations between urban constructs that shape health beyond the capability of commonly used analytic techniques. It is likely that many characteristics of cities affect health by modifying the effect of other factors that are

causally linked to health. For example, transportation routes may not be causally linked to cardiac arrest survival, but the efficacy of emergency medical services systems in reducing cardiac arrest mortality may be different in neighborhoods with easy ambulance access compared to neighborhoods that do not have easy ambulance access. Studies that are adequately powered to detect effect modification across levels need to have larger sample sizes than conventional studies aimed strictly at detecting associations.

In addition to the modifying role that characteristics of cities may play, characteristics of cities at different levels may also mediate or confound relations between other characteristics and health. For example, while municipal-level spending on public hospitals within a city may be associated with health in the aggregate, it is likely that this relation is modified by baseline quality of care in the public hospitals and mediated by access that persons with substantial morbidity have to hospital care. This latter consideration reflects the complex causal chain that most accurately reflects how urban characteristics may influence health. Ultimately, most epidemiologic analyses in urban health and across disciplines rely on assumptions of linearity for hypothesis testing. However, in complex systems, non-linear associations are common. The application of innovative methods that take into account non-linear relations may be particularly important in considering how cities may affect health (e.g., qualitative loop analysis, see Levins and Lopez, 1999).

4.0. KEY CHALLENGES FACING EPIDEMIOLOGIC STUDY OF URBAN HEALTH

Forging urban health into a coherent discipline, and advancing epidemiologic studies of how urban living may affect health, requires an appreciation of the complexities inherent to urban health research (Vlahov and Galea, 2003). As interest in urban health grows, several conceptual frameworks have been presented that suggest that a full understanding of how cities affect health may not necessarily lend itself to the easy application of a single empiric method (Vlahov and Galea, 2002). This complexity, and the features that make the study of urban health challenging, in many ways are not unique to urban health but rather are characteristics shared by the study of complicated human systems in general. In considering such systems, simple paradigms of single exposure and disease, traditionally the "bread and butter" of epidemiology, are inadequate. We consider here these challenges in the context of urban health research and discuss how they may influence the choice and application of research methods.

4.1. Specification of Research Question

Clear specification of a research question is the necessary first step in all etiologic and interventional epidemiologic research and is often one of the hardest. More specifically, the greatest challenge in the epidemiologic study of urban health is in adequate specification of research questions that address how and why urban living may affect health.

There are three primary reasons why this task may be particularly challenging in urban health. First, much of what may be considered urban health research in the literature thus far has arisen from different disciplines, using different theoretical frameworks (or sometimes from an a theoretical perspective), and applying different

disciplinary orientations and terminologies. For example, in demography and epidemiology, research into the role of urbanization in shaping health may focus on how population change in cities, resulting from migration and population growth, may influence the distribution of diseases (e.g., Yusuf, *et al.*, 2001; Peters, 1999). In contrast, the study of urbanization in sociology may focus on social activities and social organization in cities and their association with changing behaviors and their consequences. Clearly, in considering how urban living may affect health the study of both changing urban population size and of how individuals acquire different urban lifestyles are important. Useful epidemiologic research should help us understand the role of each in influencing health and behavior; however few researchers have posed questions that enable them to consider both these perspectives.

Second, many questions in urban health research do not meaningfully exist in isolation (Israel, *et al.*, 1998). Understanding how urban living affects health requires consideration of multiple, often competing, influences. Broadly speaking there may be factors in urban areas that are detrimental to health (this has previously been referred to as the "urban health penalty", see ACP, 1997), while other factors may confer "an urban health advantage" (Vlahov, *et al.*, 2005). For example, while social capital associated with group membership may be salutary (Kawachi, 1999), identification with tightly knit homogenous ethnic communities may result in spatial racial segregation that has been associated with poor health (Acevedo-Garcia, *et al.*, 2003). Continuing to consider the example of urbanization, different disciplines might study various aspects of urbanization that coexist and potentially exert varying effects on population health. This interdependence of research questions complicates the empiric task of assessing how cities may affect health and suggests that while epidemiologic contributions to the study of urban health can be invaluable, in isolation these contributions are unlikely to extend our understanding of the field. Specification of relevant research questions in epidemiologic research must at least acknowledge, if not take into account, the interrelated processes that ultimately determine health in cities and take into account the contribution that may be made by other disciplines both to framing the epidemiologic question of interest and to aiding in the interpretation of the empiric observations within their appropriate context.

Third, as is the case with all research, clear specification of a research question rests, at least implicitly, on the acknowledgement of a theoretical framework that suggests how and why the characteristics of interest may affect health. The absence of a single, agreed upon framework in the study of urban health complicates the specification of research questions in the field, as well as the interpretation of research findings. In recent years several investigators have proposed more comprehensive models that may help to unify these different strands of urban research (Northridge, *et al.*, 2003; Galea, *et al.*, 2005).

4.2. Definitions of Urban, Intra-urban Spaces, and Urbanization

Epidemiologic research is predicated to a large extent on the appropriate operationalization of the constructs of interest into simple variables. In the context of urban health research, definitional issues become critical to permit empirically rigorous analyses that are generalizable across studies. The definitions of import differ, depending on the research question being investigated (as discussed above) and whether the research in question is concerned with inter- or intra-urban comparisons. Starting with the most basic definitions, there are multiple, and inconsistent

definitions of what constitutes "urban", thus complicating and limiting the generalizability of inter-urban comparisons. No definition of urban places has been universally adopted and multiple, inconsistent definitions of urban are used by different countries, and at times within countries. For example, the U.S. Bureau of the Census defines an urbanized area in the following way: "An urbanized area comprises a place and the adjacent densely settled surrounding territory that together comprise a minimum population of 50,000 people. . . . The 'densely settled surrounding territory' adjacent to the place consists of territory made up of one or more contiguous blocks having a population density of at least 1,000 people per square mile". However, this definition is not consistent in other countries and in fact, among 228 countries on which the United Nations has data, about half use administrative definitions of urban (e.g., living in the capital city), 51 use size and density, 39 use functional characteristics (e.g., economic activity), 22 have no definition of urban, and 8 define all (e.g., Singapore) or none (e.g., Polynesian countries) of their population as urban. Official statistics (i.e., all the statistics above) rely on country-specific designations and do not use a uniform definition of urban. In specific instances, definitions of "urban" in adjacent countries vary tremendously. For example, urban definition in Bolivia includes localities with 2,000 or more inhabitants. In neighboring Peru, populated centers with 100 or more dwellings grouped contiguously and administrative centers of districts are considered urban. Compounding the difficulties in considering "urban" as a consistent definition, definitions of urban have changed over time in different ways in different countries and these differences are frequently embedded in calculations about changing urban proportions. Thus, what we may call urban in different settings may include what might otherwise be construed as city centers, peri-urban fringe cities, and densely populated isolated regions.

Intra-urban research in turn relies on the appropriate specification of intra-urban units that are theoretically meaningful to residents within cities. As discussed earlier, intra-urban spaces are typically conceived of as "neighborhoods". Conceptually, there is likely no "one" neighborhood unit that is important to the exclusion of all other units. For example, while a person may be influenced by her immediate environment (few blocks) in choice of foods purchased, it is equally plausible that safety in the larger neighborhood determines whether the same person exercises on a regular basis. Previous research has confirmed this thinking and shown that different social and environmental measures operate at different levels. For example, studies of social capital and health have been conducted at both the small neighborhood scale in Chicago and at the statewide level across the U.S. (see Sampson, *et al.*, 1997; Kawachi and Kennedy, 1997). Poverty at the state, county, city, and neighborhood levels has been linked to poor health status.

Implicit in these different contextual units of analyses is the lack of a clear consensus on the appropriate definitions of relevant intra-urban units of theoretical and empiric interest. Existing research has utilized various definitions of neighborhoods, including communities as identified by their residents, block groups, census tracts, and clusters of census tracts. Measures of neighborhood probably should be homogeneous enough to make measures such as median household income meaningful, but also be heterogeneous enough to be able to observe the effects of this variation (Pickett and Pearl, 2001). Unfortunately, as these studies have used different measures of the relevant intra-urban unit of analysis, generalizations from these observations become difficult. Further conceptual and empiric development will be necessary to clarify the appropriate use of intra-urban units of analysis and to

advance our understanding of the role of specific urban characteristics that may affect population health.

Definitions of "urban" or of the relevant intra-urban units of analysis are important aids to analysis that deal with cities at one point in time. However, it is *change* in cities over time that may be an equally, if not more important determinant of population health. "Urbanization", generally considered to refer to "population growth in cities" is also complex to measure and different methods of measuring urbanization. At its simplest level, there are several ways to measure growth in cities that in different ways may affect health. Overall, these may include the absolute annual increase in urban population size, the urban population growth rate, the level of urbanization, and the rate of urbanization. Urbanization, at its simplest level, may be calculated as the change in the proportion of the national population that is urban. However, this change in proportion is dependent both on the urban population growth, and on the relative growth of the rest of the country. There are different implications for countries and cities where urbanization is driven by rural-urban migration or international migration, compared to other countries where urbanization is largely driven by natural growth of cities. Together with changing urban proportions, changes in the absolute number of urban residents are also meaningful. Thus, while countries of vastly different sizes can share urbanization rates, these urbanization rates can represent vastly different absolute numbers of urban residents. Also, the percent of national growth that's influenced by growth in urban areas ultimately also is reliant in the change of the overall national population. So, net urban growth is again differently meaningful in the context of larger and smaller countries.

Further development in urban health requires careful consideration of how key epidemiologic units of interest–cities themselves, units within cities, and the changes in cities over time, are measured both within and across studies and what the implications are for different methods of assessment.

4.3. Cities Are Complex and Multiple Competing Influences May Be Important Determinants of Health

As discussed in several chapters in this book, cities are complex communities of heterogeneous individuals and multiple factors may be important determinants of population health in cities. For example, in order to understand the role that racial/ethnic heterogeneity plays in shaping the health of urban populations, it is important to understand both the role of segregation in restricting access to resources in urban neighborhoods (Acevedo-Garcia, *et al.*, 2003) and the potential for greater tolerance of racial/ethnic differences in cities compared to non-urban areas. Assessing how urban living may affect health raises challenges and introduces complexity that is often not easily addressed through the application of simple epidemiologic methods.

Recent epidemiologic thinking has introduced the notion that epidemiologic analyses should consider the complexity of factors that can shape individual and population health. Several observations suggest that human populations behave as complex systems. First, there are multiple examples of discontinuous changes in health in relation to monotonic changes in exposures facing human populations (Philippe and Mansi, 1998). For example, the relation between population health and several environmental exposures encompass threshold and sigmoid curves, both hallmarks of nonlinear dynamics (Maynard, *et al.*, 2003). Second, the effects of

particular exposures on human populations can linger well beyond removal of the exposure. For example, the population mental health consequences of disasters are well known to persist beyond the disaster itself (Galea, *et al.*, 2003b). Third, multiple diseases, including infectious diseases and neoplastic diseases, frequently share determinants that are affected by common environmental exposures (Koopman and Lynch, 1999; Koopman and Longini, 1994). Although none of these observations in and of themselves *define* complex systems, they provide empiric evidence that human populations exhibit complex system behaviors and as such, that epidemiologic assessment of the role of complex environments such as urban environments might benefit both from considering the contribution of disciplines such as ecology that have long considered the contribution of complex determinants and non-linear system dynamics.

4.4. Cities Are Different from One Another and May Change Over Time

Epidemiologic inquiry in health presupposes that there are identifiable (and modifiable) factors that influence health. Typically, public health studies imply, for example, that we can generalize about how different foods will affect health across individuals, at least within the confines of effect modification across groups (e.g., age groups)) or under different circumstances (e.g., at different levels of caloric intake). However, cities are characterized by multiple factors (e.g., size, population density, heterogeneity etc.) that in many ways make each city unique. The complexity of cities and of city living may mean that urban characteristics that are important in one city may not be important in others, limiting the generalizations that can be drawn about how urban living influences health. Further complicating this task is the fact that cities change over time with implications for the relative contribution of different factors in determining health in cities. For example, municipal taxation of alcohol and cigarettes may be an important determinant of alcohol and cigarette consumption in a particular city at one point in time (Grossman, 1989). However, changing social norms around smoking and alcohol use may either obviate or reinforce the influence of taxation. Returning to our built environment and health example, it may not be the quality of the built environment at one point in time that is associated with infectious disease, as much as it is the pace at which buildings are erected (or abandoned) that disrupt disease vectors and facilitate the transmission of infectious disease in urban areas. For example, it has been shown in several developing world cities, where much of the growth in urban areas is taking place, that rapid (and uncontrolled) building in dense urban areas is associated with increasing breeding grounds for mosquitoes and an increase in mosquito-borne diseases such as malaria and dengue fever (Sutherst, 2004). As such, epidemiologic inquiry into urban characteristics that affect health may do well to note both the prevailing context within which such characteristics operate and that the role of these characteristics may change over time.

5.0. THE FUTURE: WHAT IS THE ROLE OF EPIDEMIOLOGY IN THE STUDY OF URBAN HEALTH?

As we have discussed throughout this chapter, in thinking about health in cities, the perspective of urban epidemiology needs to be based on an appreciation of the complexity of living conditions and how, as an array, they affect health. In epidemiologic

studies, the traditional predominant approach to causal inference is to isolate exposures and outcomes, controlling or adjusting for confounding factors or revealing interactions. When thinking about the health of populations in cities, establishing these associations in isolation of other factors that may be equally important is problematic. The range and overlap of exposures in cities is more complex than would be suggested by inference drawn from individual risk factor-disease associations, and the degree to which they are left unconsidered makes results and priority setting incomplete. An urban epidemiology shifts the focus to how associations reported in simpler settings are observed within a more complicated urban setting that embeds multiple physical and social factors that may determine population health. In so doing, urban epidemiology must draw both on different fields of epidemiology, including categorical and exposure-based expertise, and on different disciplines including ecology, sociology, and mathematical modeling. This obviously presents challenges and frustrations.

However, this approach also has tremendous potential. We argue that the study of urban health lends itself to the creative application of methods from multiple disciplines and the nuanced appreciation of the role of multiple factors that may determine population health in cities. With the rapidly growing predominance of cities worldwide we can ill-afford to avoid focusing attention on how the complexities of urban living may affect population health. We suggest that an agenda for urban epidemiologic research, including theoretical frameworks and methodologic development, is urgently needed.

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