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CHAPTER TWO

Energized Crowding and the Generative Role of Settlement Aggregation and Urbanization

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Abstract *I describe a new approach to understanding processes of village aggregation and urbanization in the past. The key concept—energized crowding—refers to the social effects of large numbers of social interactions that take place within settlements. Demographic processes of population growth and settlement nucleation (aggregation and urbanization) lead to increased energized crowding, which, in turn, generates a variety of social outcomes. I discuss those outcomes under three headings: scalar stress, community formation, and economic growth. In this model, aggregation and urbanization are crucial processes that lead—by way of energized crowding—to many documented social outputs in both contemporary and past settlement systems. Because this is a new approach for archaeology, conceptual tools for understanding these processes must be borrowed from other social sciences. In particular, recent research on settlement scaling provides empirical and theoretical support for the notion that aggregation and urbanization were of fundamental importance in generating social change in the past.*

Population aggregation—the concentration of formerly dispersed people into villages, towns, and cities—is one of the most consequential processes in the history of human society. When people come together in a settlement, the number and level of interactions among individuals increase exponentially, and these interactions have generative power. That is, they bring about a variety of social changes, both positive and negative. Research by sociologists and anthropologists has tended to focus on the negative consequences of urbanization—increased levels of stress, crime, poverty, and alienation (Redfield 1941; Wirth 1938). Research by economists and geographers, on the other hand, emphasize the positive consequences of aggregation. The acceleration of face-to-face social interaction in larger and denser settlements stimulates knowledge transfer, technological innovation, and economic growth (Duranton and Puga 2004, 2014). One well-documented finding for contemporary cities is that as cities grow larger, their per capita productivity increases—individuals are more productive in larger cities (Bettencourt 2013; Pumain 2012).

These positive and negative consequences of aggregation and urbanization are two sides of the same coin. Whether talking about the aggregation of small early farming groups into villages (e.g., Birch, Gaydarska, and Ryan this volume) or the processes of rural-to-urban migration that lead to urbanization in the developing world today, the results are similar. Increased numbers of people living in close contact activate a process that architectural historian Spiro Kostof called *energized crowding*: "Cities are places where a certain energized crowding of people takes place. This has nothing to do with absolute size or with absolute numbers; it has to do with settlement density" (1991:37). While research suggests that the magnitude of the social effects of energized crowding does, in fact, depend on both density and absolute population size (e.g., Bettencourt 2013; Fletcher 1995), Kostof's concept helps us understand processes of aggregation and urbanization.

In this paper, I argue that settlement aggregation and urbanization have been fundamental processes in structuring and generating change in human settlements in the past and present. Energized crowding is the pathway that connects these processes to their social consequences. It lies at a key causal nexus between demographic processes and social outcomes. I review a variety of empirical findings and theoretical perspectives that describe the role of energized crowding. In some scholarly traditions—for example, urban economics and the social reactors model of settlement scaling—face-to-face interaction is an explicit component of current models. In others—such as sociology and anthropology—such interactions are implicit, but important in theory and research.

CITIES, POPULATION, AND ENERGIZED CROWDING: THE POWER OF FACE-TO-FACE INTERACTIONS

I propose a basic causal model to portray the generative roles of population growth and aggregation (Figure 2.1). This model is supported by a wide variety of theoretical and conceptual approaches in the social sciences. There is not space to explore all of these here, so I list the relevant approaches in Table 2.1. My model contains two types of demographic process that create increased face-to-face contacts or energized crowding: population growth (which I separate into population growth per se and increases in population density) and population concentration (divided here into village aggregation and urbanization). Energized crowding, in turn, generates a variety of social outcomes that I organize under three headings: scalar stress, community formation, and economic growth. This classification is somewhat arbitrary since the demographic drivers and social outcomes are all closely interrelated.

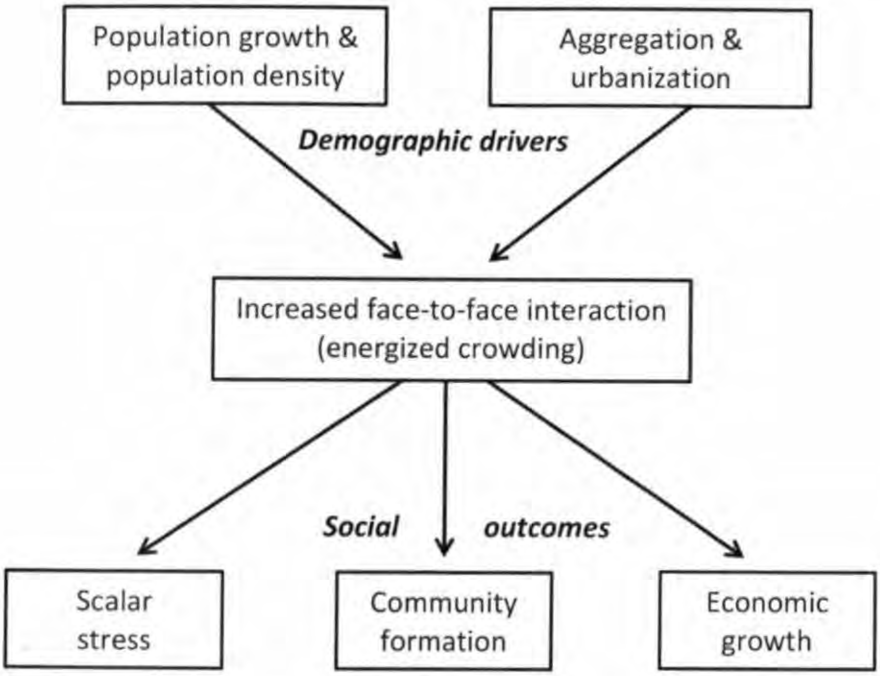

FIGURE 2.1 Drivers and outcomes of energized crowding.

POPULATION SIZE AND DENSITY

The notion that population growth, population size, and population density generate effects in cities resonates with a long tradition of research on cultural evolution in anthropology and archaeology. The role of population growth in generating cultural evolution was discussed by sociocultural anthropologists in the 1950s and 1960s (Carneiro 1962; Naroll 1956), and then it was taken up by archaeologists. After debates about the role of population pressure in generating various social changes in the past (Spooner 1972), archaeological consensus settled on the notion that while group size is correlated with sociopolitical complexity (Feinman 2011; Johnson and Earle 2000), population pressure is rarely the sole driver of cultural change and evolution. But in the more limited domain of agricultural intensification, Netting (1993) fleshed out Boserup's (1965) model and demonstrated the role of population growth in generating agricultural and social changes.

A parallel line of analysis outside of anthropology led to the development of demographic-structural theory by sociologist Jack Goldstone (1991, 2002). This approach, later elaborated by Turchin and Nefedov (2009), examines the joint roles of demographic variables and macrosociological variables in generating change in human institutions. Most of the research I review below—on the role of energized crowding in generating scalar stress, community formation, and economic growth—is based, explicitly or implicitly,

TABLE 2.1
THEORETICAL APPROACHES TO THE EFFECTS OF POPULATION GROWTH AND AGGREGATION

Outcome	Theoretical Approach
Population growth leads to:	
Cultural evolution	Archaeological cultural evolution
Agricultural intensification	Boserup/Netting
Institutional change	Demographic structural theory
Economic growth	Urban economics
Community formation	Sociology; political economy
Scalar stress	Cognitive cultural evolution
Increased population density leads to:	
Scalar stress	Settlement growth theory
Negative social outcomes	Urban sociology; environmental psychology
Economic growth	Urban economics
Village aggregation leads to:	
Scalar stress	Settlement growth theory
Community formation	Settlement growth theory
Urbanization leads to:	
Negative social outcomes	Urban sociology; public health
Community formation	Urban sociology; neighborhood theory
Agglomeration economies & growth	Urban economics; economic geography

on the notion that population growth is a cause of energized crowding. The fact that these outcomes are reported in a variety of disciplines—archaeology and anthropology, urban economics, political science, sociology, and cognitive cultural evolution (Table 2.1)—points to their widespread validity and applicability.

Whereas population growth leads to a variety of social changes at the societal or regional level, the effects of increased population density are felt primarily at the level of the settlement or community. As discussed below, there has been extensive archaeological research on the connection between population density and scalar stress (for major studies, see Adler and Wilshusen 1990; Birch 2013; Fletcher 1995; Jennings 2016), which I group together under the label "settlement growth theory" (Table 2.1).

VILLAGE AGGREGATION AND URBANIZATION

Research on the generative effects of village aggregation has been carried out almost exclusively by archaeologists employing settlement growth theory. Scalar stress, as discussed below, can lead to a variety of outcomes, one of which is the development of institutions and facilities that promote community formation. This is a major theme of research in the U.S. Southwest, where integrative facilities, such as kivas, promote community formation (Adler and Wilshusen 1990; Schachner 2010; see also Ryan as well as the related work of Birch and Fernández-Götz in this volume).

The role of urbanization in creating negative social outcomes—from crime and poverty to physical and mental health problems—has long been a major theme of social science research (Kornhauser 1978; Nisbet 1966; Wirth 1938). Within urban sociology and neighborhood theory (e.g., Chaskin 1997; Sampson 2012; Smith et al. 2015), discussions of the positive effects of urbanization have focused on community formation, whereas urban economics and economic geography have emphasized economic growth and agglomeration effects as positive outcomes. Recent suggestions by archaeologists that urbanization may have preceded state formation (Jennings 2016; Wengrow 2015) provide intriguing empirical—if not yet theoretical—support for the causal role of urbanization in social change. Further support for that role comes from new research in settlement scaling, reviewed below.

Communication, Energized Crowding, and Cities

An increasingly popular perspective in the social sciences and history sees the primary purpose of cities as promoting social interaction and communication among residents. Some of the earliest expressions of this view were given by urban planners: "Cities were evolved primarily for the facilitation of human communication" (Meier 1962), and "more than anything else, the city is a communication network" (Lynch 1981:334). The implications for aggregation were elaborated by social historian Charles Tilly:

> H.A. Innis, his followers Marshall McLuhan, Richard Meier and Allan Pred have all argued, in their own ways, that where communications were both costly and crucial to the enterprises men were carrying on, men have agglomerated in towns and cities. The agglomeration is a response to high distance-cost. But, as these authors have usually pointed out, the relationship is reciprocal. The high premium placed on efficient communications stimulates urbanites to invent new media which will carry large volumes of information far and fast at low cost (1974:226).

Social interaction and communication among closely spaced residents create the "energized crowding" noted by Kostof. Historian Fernand Braudel expresses similar ideas: "Towns are like electric transformers. They increase tension, accelerate the rhythm of exchange and constantly recharge human life" (1981:479). In a study of contemporary urban economics, geographers Michael Storper and Anthony Venables (2004) refer to this characteristic of cities as "buzz." In this paper, I use the phrase "energized crowding" to refer to the various dynamic aspects of face-to-face social interaction in human settlements. In a related formulation, Lynch (1981:187–203) argued that the purpose of cities was to give their residents access—access to other people, to certain activities, to material resources, to places, and access to information.

The concept of energized crowding contributes greatly to explanations for many of the consequences of early aggregation and urbanization around the world. Before proceeding, though, I should note that this line of thought is a radical departure from traditional archaeological models of early cities and complex societies. Until quite recently, most archaeological accounts of early states assumed that all past rulers were powerful and despotic, and were willing and able to control many aspects of peoples' lives, whether through economic or ideological domination (for critiques of this approach outside of archaeology, see du Gay 2012; Mann 1986:526–527). Within archaeology, the primary challenge to this statist approach has been Blanton and Fargher's (2008) identification of both collective and autocratic rule in premodern polities. They show that the Classical Greeks (see Ault this volume) were not the only ancient society to create a collective form of government. Outside of archaeology, the prominence of generative, or bottom-up, social processes—often called self-organization or spontaneous order—has been recognized for many decades (Cronk and Leech 2013; Epstein 1999; Hakim 2007; Hayek 1967; Jacobs 1961; Mitchell 2009; Ward 1973). Indeed, most of the theoretical approaches listed in Table 2.1 emphasize the power of generative forces instead of top-down, centralized, decision making. When archaeologists abandon their obsession with statist models of all-powerful rulers, our understanding of many past social phenomena will advance more rapidly.

In their article titled "Buzz: Face-to-Face Contact and the Urban Economy," Storper and Venables (2004) list four broad functions of face-to-face contact in cities (Table 2.2). While their treatment focuses exclusively on contemporary capitalist urban economies, these basic functions of face-to-face interaction apply equally well to cities and towns before the modern era. For example, Storper and Venables point out that

TABLE 2.2
MAJOR PROPERTIES OF FACE-TO-FACE INTERACTION
(AFTER STORPER AND VENABLES 2004:354)

Function	Advantages of Face-to-Face Interaction
Communication technology	High frequency Rapid feedback Visual and body language cues
Trust and incentives in relationships	Detection of lying Co-presence is a commitment
Screening and socializing	Acquisition of shared values
Rush and motivation	Performance and display

face-to-face interaction as a communication technology is especially important "when much of the information to be transmitted cannot be codified" (2004:353), a condition prevailing in most premodern economies. Its role in establishing trust is a fundamental part of cooperation theory (Hechter 1987), and this insight is now being applied by archaeologists (Carballo 2013). One way that social interactions are affected by the built environment is through viewshed: who can see what (and whom) from where (see Kaiser this volume).

From a comparative perspective, the powerful role of face-to-face interaction in structuring urban societies and generating change is one of the major continuities between contemporary and ancient cities. The following quotations, from urban economist Edward Glaeser, apply equally well to ancient settlements and to the contemporary cities about which Glaeser writes, "The central theme of this book is that cities magnify humanity's strengths. Our social species' greatest talent is the ability to learn from each other, and we learn more deeply and thoroughly when we're face-to-face" (2011:250), and, "Cities enable the collaboration that makes humanity shine most brightly. Because humans learn so much from other humans, we learn more when there are more people around us" (2011:247). I now turn to the question of how energized crowding generates a variety of social outcomes in cities and other settlements (Figure 2.1).

The Effects of Energized Crowding

Energized Crowding Generates Scalar Stress

Scalar stress is a term first used by archaeologist Gregory Johnson (1978, 1982) to describe the increase in intragroup conflict that happens as the size of the social group increases; ethnographer Roy Rappaport (1968:116) had earlier used the term *irritation coefficient* to describe the predictable growth in disputes as population density increased among tribal villagers in highland New Guinea. The number of potential social interactions of each individual increases exponentially with the size of the interacting social group. As certain thresholds are reached, conflict and psychological stress can increase dramatically (Hopstock et al. 1979; Kennedy and Adolphs 2011). Scalar stress is the negative face of energized crowding.

I broaden the concept of scalar stress here and use it as a label for the many negative effects of growth in population and population density identified by social scientists. More than a century ago, Simmel observed, "Every quantitative extension of a group requires certain qualitative modifications and adjustments" (1898:834). Since then, numerous social scientists have discussed the negative implications of large, dense urban populations. To begin, scalar stress has negative social effects at the individual level. It can lead to more transitory urban social relations and urban anomie (Mayhew and Levinger 1977), as well as psychological stress (Evans 2001). It also produces larger structural effects, such as poverty, crime, delinquency, and public health problems (O'Brien 2009; Spruill 2010). In the field of cognitive cultural evolution, scalar stress is posited as occurring above key population thresholds, such as Dunbar's number (Dunbar 2011), at which point it causes a variety of sociocultural changes (Coward and Dunbar 2014). This cognitive approach, however, has been criticized by sociologists and anthropologists (de Ruiter et al. 2011; Wellman 2012).

Archaeologists have discussed scalar stress primarily in terms of early village aggregation and growing early urban populations. A consensus view has developed that identifies the following processes as major outcomes of scalar stress in ancient times: village fission, specialization in roles, the development of social hierarchies, and increased group-integrating ritual activity (Alberti 2014; Bandy 2004; Fletcher 1995:ch. 4; Jennings 2016:ch. 4). Architecturally, scalar stress was reduced in early communities by enclosure of spaces and the spatial specialization of activities in the built environment (Fletcher 1995:ch. 6; Kent 1990), as well as by the development of integrative architectural features that promoted cohesion through group ritual (Adler and Wilshusen 1990; see also Birch 2013). Several chapters in the present volume (e.g., Birch, Harrison and Bilgen, Kelly, and Sastre and Currás) examine these themes.

The large volume of research by social scientists and archaeologists on scalar stress—conceived broadly—clearly shows its generative role in creating changes in human societies and behavior. Most authors are careful to emphasize that the negative effects of population are generated not just by the number of people but by the number of social interactions. This, in turn, is a function of both population size and density. In other words, the culprit is not just the number of people but the number of potential interactions. It is through these increased social interactions that energized crowding generates scalar stress. But energized crowding also has socially beneficial or positive outcomes, particularly community formation and economic growth.

ENERGIZED CROWDING DRIVES COMMUNITY FORMATION

Communities are primary sites of social interaction; indeed, a classic anthropological definition of community is "the maximal group of persons who normally reside together in face-to-face association" (Murdock 1949:79). In sociological theory going back to Emile Durkheim, energized crowding—intensive social interaction—is seen as the primary force that generates communities (Figure 2.2).[1] This line of thinking continues today both among archaeologists working on settlement aggregation (see Birch, Fernández-Götz, Osborne, and Ryan this volume) and in studies of community formation from a political economy perspective. For example, economists Sam Bowles and Herbert Gintis define community as follows:

> By community we mean a group of people who interact directly, frequently and in multifaceted ways. People who work together are usually communities in this sense, as are some neighbourhoods, groups of friends, professional and business networks, gangs, and sports leagues. The list suggests that *connection, not affection,* is the defining characteristic of a community. Whether one is born into a community or one entered by choice, there are normally significant costs to moving from one to another (2002:F420; emphasis added).

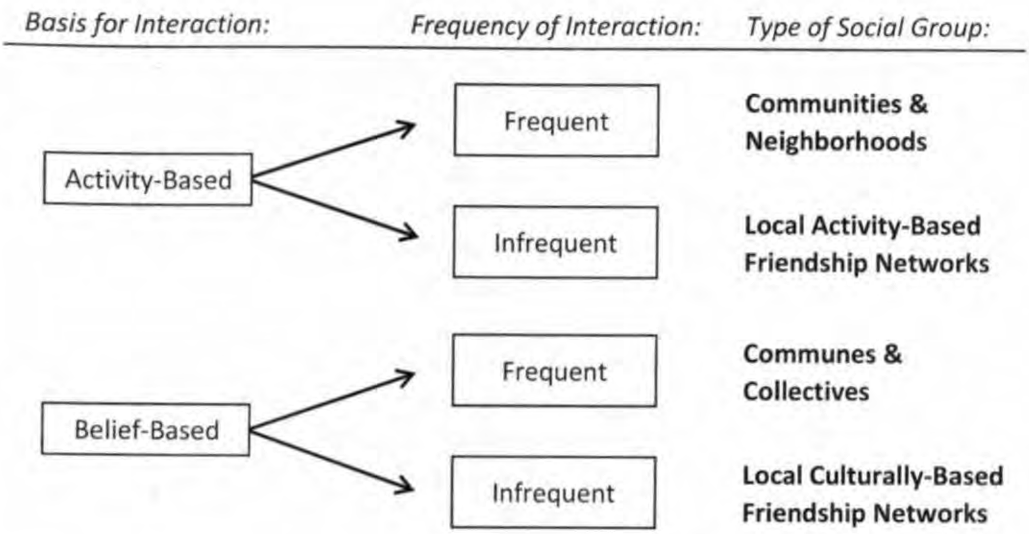

FIGURE 2.2. Social interaction and community formation (redrawn based on Brint 2001:10).

Urban planners see social interactions—with friends, neighbors, and other residents—not only as forces that generate community but as the force that creates successful cities and towns. This is because social interaction—particularly in or near neighborhood physical facilities, such as parks, playgrounds, and pedestrian-friendly streets—is a key dimension of social cohesion in cities (Jacobs 1961; Smith 1975). Stable neighborhoods facilitate social interaction, which promotes social cohesion or integration (Brower 2011).

The establishment and formation of successful communities have a variety of positive social effects. In the words of Bowles and Gintis:

> [C]ommunities solve problems that might otherwise appear as classic market failures or state failures: namely, insufficient provision of local public goods such as neighborhood amenities, the absence of insurance and other risk-sharing opportunities even when these would be mutually beneficial, exclusion of the poor from credit markets, and excessive and ineffective monitoring of work effort. Communities can sometimes do what governments and markets fail to do because their members, but not outsiders, have crucial information about other members' behaviours, capacities, and needs. Members use this information to uphold norms (2002:F422–F423).

The ability of communities to act—effectively and with positive outcomes—lies at the heart of the work of political economist Elinor Ostrom (1990, 2005). One of her basic arguments parallels precisely the conclusions of Bowles and Gintis: local communities can manage common-pool resources more successfully and sustainably than either states (government ownership) or markets (privatization). For Ostrom, one of the key attributes that allows communities to be successful is the prominence of face-to-face communication, which promotes trust, reputation, and reciprocity.

A major spatial outcome of community formation in growing cities and towns is the generation of spatial clusters of interaction, or neighborhoods. Most likely because of scalar stress, in the form of limits—whether cognitive or social—on the numbers of social interactions people can readily handle, neighborhoods have become universal traits of cities, from the past to the present (Smith 2010). Where authorities design settlements, they almost always include some form of neighborhood organization, and where settlements develop from bottom-up social processes, neighborhoods form without central direction (Smith et al. 2015). The creation of neighborhoods and other social communities is shaped by the built environment, a relationship stressed by advocates of the New Urbanism. For example, Talen (2000) proposes a causal chain that runs from the built environment, through social factors, to social interaction and the formation of communities (Figure 2.3). Energized crowding does not exert its effects in a spatial vacuum—the specific configuration of buildings and spaces plays an important role in generating its outcomes, both positive and negative. This feature provides one avenue by which archaeologists can study energized crowding.

ENERGIZED CROWDING LEADS TO ECONOMIC AND URBAN GROWTH

Urban agglomeration refers to the spatial concentration of economic activities in cities. Agglomeration effects are major causes of economic growth in cities today, and much work in urban economics and economic geography is devoted to understanding how these processes operate (Fujita et al. 1999; Glaeser 2008; Storper 2013). Energized crowding is viewed by economists as a basic component of urban agglomeration. In their discussion of "buzz," or energized crowding, Storper and Venables conclude, "We speculate that there is a superadditivity in these effects [the effects listed in Table 2.2 above], generating increasing returns for the people and the activities involved" (2004:365). These effects of social interactions on growth have been called a "social multiplier" (Glaeser et al. 2003; see also Helsley and Zenou 2014). Did such effects operate in past settlements? The answer is yes, but only if we define the concept of agglomeration more broadly, a task that has barely begun (Scott and Storper 2015).

Duranton and Puga (2004) explore what they call the "microfoundations" of agglomeration economies. These are divided into three broad categories: (1) *sharing*

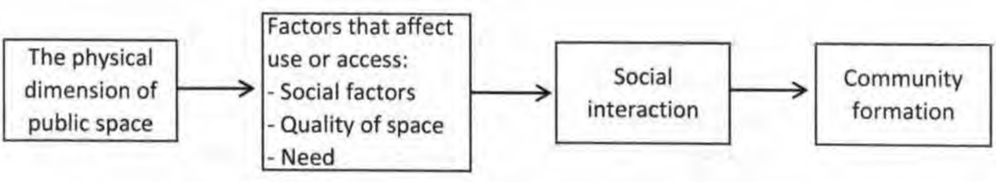

FIGURE 2.3. The built environment and community formation (redrawn based on Talen 2000:348).

refers to linkages among local production facilities, labor pools, markets, and public goods; (2) *matching* describes the way people and jobs pair up more efficiently in agglomerated economies; and (3) *learning* refers to the flows of knowledge and information within cities. Their discussion of agglomeration economies—like most work by economists and economic geographers—is clearly tailored to the capitalist economy, and to contemporary urban and national systems of governance. But these basic forces that generate agglomeration or concentration of activity in cities can be generalized to fit premodern cities.

The first step in broadening the applicability of the concept of agglomeration is to acknowledge that in many or most premodern cities political and religious institutions were more important than economic institutions for the operation and growth of cities. Scott and Storper suggest that early cities experienced agglomeration effects in "activities such as political administration, ceremonial and religious pursuits, craft production, and market trading" (2015:4). Following the scheme of Duranton and Puga (2014), the following activities can be suggested as components of premodern agglomeration:

1. Sharing. Many of the shared goods and places of agglomeration can be interpreted as club goods or toll goods. That is, they have low rivalry (use by one person does not compromise use by others), but moderate to high excludability (some people can be prevented from access). In past settlements, such goods included public facilities, such as marketplaces, temples, and formal open spaces. For urban residents, these were public goods, available to all (that is, they had low rivalry and low excludability), but from a societywide or a regional perspective, these facilities were urban club goods—they were limited to the people who resided in, or visited, the city. These were places that brought people together in settings that promoted social interaction, allowing goods and ideas to be shared (for discussion of club goods and public goods, see Ostrom 2007 or Cronk and Leech 2013).

2. Matching. This feature of agglomeration economies, which emphasizes firms and wage labor, seems less relevant to cities and settlements before the modern era.

3. Learning. Learning and knowledge transfers lie at the heart of modern agglomeration economies and urban growth (Glaeser et al. 2003; Ioaniddes 2012). Information about goods, prices, and opportunities "spills over" among urbanites, leading to economic and urban growth. In the past, we should expect similar processes for information about goods and prices, although the effects were almost certainly much weaker prior to the Industrial Revolution. But particularly in political capitals, information about taxes, warfare, corvée labor, crops, and ceremonies would have been exchanged in settlements, allowing agents from farmers to nobles to modify their

> activity. In some cases, such learning contributed to urban growth. In this way, energized crowding in settlements stimulated growth and expansion, not only in the economy but in the political and religious realms also.

In agrarian societies with dispersed populations, one mechanism that promoted sharing and learning was the periodic movement of people into and out of nucleated settlements. Farmers came into town to attend a market or participate in a ceremony, and these activities promoted sharing and learning to a greater extent than might be expected for dispersed populations.

Perhaps the strongest evidence for the claim that energized crowding led to the growth of settlements in the ancient world comes from research in settlement scaling, to which I now turn.

SETTLEMENT SCALING AND GENERATIVE PROCESSES

The conceptual approaches reviewed above furnish a background for current models of settlement scaling in past and contemporary urban systems. Settlement scaling is part of a new perspective, arising from both empirical studies and theoretical considerations, developed at the intersection of a number of disciplines. The scaling of contemporary cities—"urban scaling"—was the first realm to develop. Urban scaling work shows how contemporary cities share certain predictable quantitative properties. A number of quantitative urban variables (surface area, amount of infrastructure, and a broad series of both positive and negative social outcomes) scale with population in a predictable manner (Bettencourt 2013; Pumain 2012; West 2017; Youn et al. 2016).

"Settlement scaling" is a broadened perspective that extends the domain of scaling research in two ways. First, consideration is given to urban systems prior to the modern era, using both historical and archaeological data. Recent studies show that the same quantitative patterns identified for contemporary urban systems also hold for city systems in early times (Cesaretti et al. 2015; Ortman et al. 2014, 2016). Second, nonurban or village settlement systems have now been included in the domain of settlement scaling, with the remarkable result that these same quantitative patterns also hold for village-level settlement systems (Ortman and Coffey 2017). These two sets of results provide strong empirical support for the generative role of aggregation and urbanization in creating changes in human society. In this section, I review very briefly the empirical and conceptual aspects of current research in settlement scaling (see also Raczky this volume).

CONTEMPORARY URBAN SYSTEMS

The existence of regularities in the sizes of cities within a given urban system has been recognized for many decades. City size in many systems conforms to a power law distribution (a distribution with many more small values and fewer high values than the normal distribution) known as Zipf's law or the rank-size rule. In these systems, the second-largest city has half the population as the largest city, the third-largest has one-third the population, and so on (Mitchell 2009:ch. 17). Archaeologists have used Zipf's law to investigate ancient settlement systems, under the label of "rank-size analysis" (Drennan and Peterson 2004; Johnson 1981; Smith 2005); most of these studies have focused on deviations from the rank-size rule, such as urban primacy (the label for settings where the largest settlement is larger than predicted by the model).

Research on urban scaling extended this search for power law regularities in city size by using city population to predict a series of quantitative urban variables (Bettencourt et al. 2007, 2010; Pumain et al. 2006). Empirical studies of contemporary city size identified some striking regularities in these data. These regularities are not about outcomes for individual cities, but rather they pertain to observable patterns of a distribution within an urban system. The quantitative patterns of greatest interest are expressed by a parameter called ß, which is the exponent of the power law. There are three classes of relationship between urban variables and city population: (1) linear scaling in which ß is equal to 1; the quantity in question increases at the same rate as population; (2) sublinear scaling in which ß is less than one; the quantity increases at a lower rate than population; and (3) superlinear scaling in which ß is greater than one; the output increases at a greater rate than population.

Several quantitative urban measures exhibit sublinear scaling with highly regular quantitative expressions. The area of a city, for example, increases with population with a ß of close to two-thirds (0.67). This means that the per capita area decreases with city size; larger cities are denser than smaller cities. Similarly, the total length of urban infrastructure (roads, cables, etc.) also increases with population with a ß of two-thirds. This makes sense—if city A is twice as large as city B, it does not need twice the amount of roads since some of the increased traffic can use the existing roads. The remarkable thing about these relationships is their regularity across urban systems (Bettencourt 2013).

More surprising than sublinear scaling are cases of superlinear scaling. A wide range of measures of social output—from income, wealth, and innovation to crime and poverty rates—exhibit superlinear scaling with city population. In other words, larger cities on average not only have more wealth or crime than smaller cities but they have larger per capita rates of these measures than smaller cities. This finding fits with long-standing social science research, reviewed above, showing that urbanization and urban growth have both positive and negative outcomes. Figure 2.4 shows data for superlinear scaling among contemporary U.S. cities compared with pre-Spanish settlements in the Mantaro region of the Andes; these data are from Bettencourt (2013) and Ortman and his colleagues (2016). Power law distributions are often graphed using a logarithmic transformation which produces a linear pattern (whose slope is ß) amenable to analysis with standard linear least-squares regression analysis. In Figure 2.4, the black lines mark a ß of 1.0 which would indicate linear scaling. The dotted lines show the prediction from theory for superlinear scaling (ß of 1.17), and the gray lines are the best fit lines (A: ß of 1.13; B: ß of 1.14).

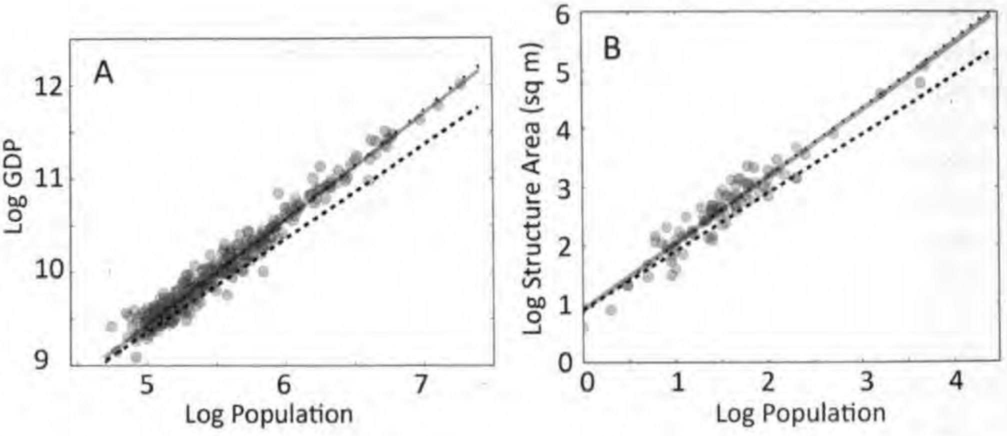

FIGURE 2.4. Superlinear scaling of economic output with population in modern and ancient settlement systems. A) GDP (Gross Domestic Product) in U.S. cities (Bettencourt 2013), B) structure area in prehispanic Andean settlements (Ortman et al. 2016). For both graphs, the dashed line shows the linear plot, the gray line is the best fit to the data, and the dotted line shows the predicted slope.

THE SOCIAL REACTORS MODEL

The data on sublinear and superlinear scaling in contemporary cities accumulated during the early 2000s. In 2013, Bettencourt published a quantitative model that predicts the empirical findings from a small number of variables. His model is based on the number of people in a settlement, the distance they can travel, the probabilities they will encounter other people, and the average output or productivity of each person. This is a network model in which the built environment acts to promote or hinder movement and interaction. The quantitative expression of these variables (for the formulae, see Bettencourt 2013) produces ideal or theoretical findings that predict quantitatively how urban measures should scale with city population. In fact, the empirical data match the predictions rather closely. In Bettencourt's words, "These results also suggest that, despite their apparent complexity, cities may actually be quite simple: Their average global properties may be set by just a few key parameters" (2013:1438).

Bettencourt calls his model the "social reactors model" of urban dynamics. Superlinear scaling indicates that the actions of individuals in cities yield per capita outputs greater than would be predicted by linear scaling alone. Cities are social reactors, and the bigger they are the greater the per capita output. This model can be seen as a kind of microfoundation for the notion, discussed above, that energized crowding generates changes in human settlements. Or, looked at from another perspective, the model of energized crowding provides a broad social science framework for Bettencourt's quantitative model of urban scaling.

Expansion of the Framework to Premodern Settlement Systems

Once the empirical findings of scaling regularities within systems of modern cities and the behavioral mechanisms of the social reactors model were established, an obvious question was whether this approach would also yield fruitful results for cities before the modern era. The basic assumptions of the social reactors model do not depend on contemporary economic institutions (the capitalist economy, wage labor, a monetary economy), and there is no obvious a priori reason why they should not hold for early or non-Western settlement systems. The next task was therefore to gather data to test the scaling models for past urban systems.

Ortman assembled the first set of archaeological data to evaluate scaling models in the distant past. He showed that both site area and wealth (using house size as a proxy for wealth) in the Aztec period Basin of Mexico scales with site population with the same scaling exponent as predicted by Bettencourt's theory and as found empirically for contemporary cities (Ortman et al. 2014, 2015). Given these initially promising results, the Social Reactors Project was formed in 2014 by Luís Bettencourt, Jose Lobo, Scott Ortman, and myself in order to explore the scaling models and other quantitative urban expressions in ancient and non-Western societies (see http://www.colorado.edu/socialreactors/). Our results to date have confirmed the presence of similar scaling regularities in a number of early urban systems, including city area in Medieval Europe (Cesaretti et al. 2015) and wealth in the Inca-period Andes (Ortman et al. 2016). Figure 2.4B shows the scaling of wealth against population for the latter region, resulting in a ß identical to that reported for contemporary economic output.

Recent research has now extended these findings to the settlement systems of small-scale farming groups that do not qualify as "urban" in most senses of that term. Two separate village settlement systems in prehistoric North America exhibit superlinear scaling of wealth and population (Ortman and Coffey 2017), and a number of twentieth-century peasant settlement systems in Mesoamerica and the Near East show the predicted sublinear scaling of area with population (Cesaretti 2016). A study of formal public plazas in ancient Mesoamerican settlements shows consistent sublinear scaling of plaza size with city population, but with values of ß that match neither prior empirical patterns nor theoretical predictions (Ossa et al. 2017). These new studies are summarized in Table 2.3; the close match between observed archaeological values for ß and the predicted values is striking.

Discussion

The settlement scaling research reviewed above has two immediate implications for the analysis of settlement aggregation and urbanization in the past. First, the fact that village settlement systems exhibit the same scaling regularities as contemporary and premodern urban systems implies that processes of village aggregation and urbanization are expressions of the same or similar underlying social dynamics. As settlements—whether

TABLE 2.3
QUANTITATIVE SCALING REGULARITIES IN PREMODERN SETTLEMENT SYSTEMS

Variable	Scaling Coefficient	Examples	Societal Type	Citation
Area	*2/3 (0.67)*	*Predicted value*		*Bettencourt 2013*
	0.57 to 0.75	Contemporary cities		Bettencourt 2013
	0.58 to 0.74	14th-century Europe	A	Cesaretti et al. 2015
	0.73	Basin of Mexico, Aztec period	A	Ortman et al. 2014
	0.66, 0.70	Late Horizon Andes	A	Ortman et al. 2016
	0.66	Mesa Verde region	V	Ortman and Coffey 2017
	0.67	Middle Missouri region	V	Ortman and Coffey 2017
	0.62 to 0.91	20th-century peasant systems	P	Cesaretti 2016
	0.65	Imperial Roman cities	A	Hanson and Ortman 2017
Wealth	*7/6 (1.17)*	*Predicted value*		*Bettencourt 2013*
	1.10 to 1.22	Contemporary cities		Bettencourt 2013
	1.18	Basin of Mexico	A	Ortman et al. 2015
	1.14	Late Horizon Andes	A	Ortman et al. 2016
	1.17	Mesa Verde region	V	Ortman and Coffey 2017
	1.19	Middle Missouri region	V	Ortman and Coffey 2017
Plaza area	0.40, 0.61	Contemporary cities		no studies
		Mesoamerica	A	Ossa et al. 2017

Key to societal types: A: agrarian state, V: village system, P: peasant component of nation-state.

villages or cities—grow through immigration (and natural increase), they generate outputs with similar quantitative expressions. Second, the social reactors theory—which postulates energized crowding as the basic process that generates growth and quantitative regularities among systems—explains the observed patterns of aggregation and urbanization as the outcome of the increased social interactions created by those demographic processes.

These findings require a number of changes in the way that archaeologists think about past settlement dynamics and urbanization. First, these results challenge the traditional, strong separation of concepts of urban and nonurban. Past emphases on the concepts of city and urbanism, and their rigorous definition, have hindered scholarly understanding of fundamental human settlement processes. Archaeologists and others have long devoted attention to partitioning settlements into the categories of urban and nonurban. The urban category carries greater prestige, leading archaeologists working on early sites to distort definitions of urbanism so that their sites will qualify (e.g., Heckenberger 2009), or to propose definitions of special types of city (e.g., low-density agrarian city) that permit their sites to enter into the rarified realm of the urban (Fletcher 2009). Definitions are useful tools—particularly for comparative analysis (Smith 2016)—but they can also impede our understanding.

This has been the case in the realm of demography and settlement size. Because the study of villages and village aggregation has been carried out independently from research on cities and urbanization, scholars have been slow to recognize the many similarities between these two domains. The common elements are the demographic and spatial attributes of individuals who move into and among settlements, and who interact socially within settlements. These processes of movement and interaction generate social and economic effects, and it is starting to become clear that these processes occur in many kinds of settlements—from villages to cities, and in the ancient and modern worlds. Indeed, the chapters in this volume provide numerous examples of these processes.

The second change needed in archaeological approaches to settlement dynamics and urbanization is an expanded investigation of the quantitative relationships between demographic and social variables in ancient settlement systems (see Table 2.3). We need to examine these patterns in a larger number of contexts in order to explore their boundaries and limits. Just how extensive or universal are these patterns? Do they apply in some situations but not others?

Third, the identification of energized crowding as a key causal nexus in explaining a variety of social outcomes requires archaeologists to look beyond anthropology and archaeology for the conceptual tools to understand settlement changes in the past. Energized crowding—a process based on the increased social interactions that come from population growth and aggregation—is a phenomenon that has been poorly explored in the disciplines of anthropology and archaeology. Other fields have better models and theories in this area, and archaeologists need to take advantage of them in order to explain the regular (and important) empirical patterns we identify in past settlement systems. Our data, in turn, has a crucial role of play in the explanation of processes of demography, urbanization, and social change—not only in the deep past but in the world today.

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Note

1. A common approach to communities in archaeology diverges from social science consensus in emphasizing idealist and social constructionist models that posit shared meanings about identity as the main factor that creates communities (Canuto and Yaeger 2000). For a critique of this approach and how it serves to isolate archaeology from the social sciences, see Smith (2018).

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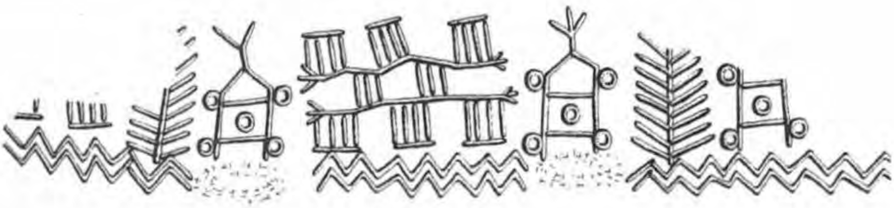
SECTION I



Coming Together: Origins and Processes