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The Embodied Multisystemic Resilience of Architecture and Built Form

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Introduction

In Italian neorealist cinema, filmed within the ruins of European cities destroyed by World War II, characters are depicted inhabiting a world in which they do not know how to perceive, feel, act, reflect, or relate that which surrounds them. In scenes of returning to daily life in the aftermath of such destruction, the actors express, what French philosopher Gilles Deleuze refers to as "sensorimotor breakdowns." Deleuze utilized an "operative" history of cinema to develop philosophical insight into contemporary life. In other words, cinema is used to explain concepts of being and time developed over the 20th century, especially in relation to the European trauma of two world wars. Deleuze's use of cinema to describe the human sensorimotor system integrates the cognitive theories of Henri Bergson with C. S. Peirce's logical and pragmatic systemic classification of human habitual reasoning (Bergson, 1907/1983, 1896/1991; Deleuze, 1986, 1989; Pierce, 1998). In *Creative Evolution*, Bergson (1907/1983) states that the sensorimotor system consists of "the cerebro-spinal nervous system together with the sensorial apparatus in which it is prolonged and the locomotor muscles it controls" (p. 124).

Environmental historian and activist Jean Gardner brought the concept of embodying resilience to architectural education as an experiential teaching module that begins with the remarkable agility of the human sensorimotor system to adapt to an often uncertain world that passes by and surrounds us (Gardner, 2019). This sensorimotor system is schematized by Deleuze into cycles of perception, affection, impulse, action, reflection, and relation images. The cyclical dynamics of these images, occurring rapidly in succession, form the patterns of

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our habits. However, we all are familiar with sensorimotor breakdowns when experiences are new and we do not know how to act. What is of interest are historical conceptualization of the human body/organisms as an information feedback system and a way of embodying multisystemic resilience in architecture and built form (McGrath & Gardner, 2007).

Italian architect Saverio Muratori (1960; Muratori, Bollati, Bollati, & Marinucci, 1963, 1967, 1973) provides an operative history of the built environment and, like Deleuze with cinema, identifies a cognitive breakdown in postwar Europe as a crisis that interrupted the organic continuity of city building traditions and consequently social-natural relations. In three research projects, he developed what he called "studies on an operative urban history" of architecture from the scale of individual buildings and rooms to regional and continental territories shaped by civilization. His notion of an operative history is embodied in the innumerable acts of world making in city building itself, rather than contemplative and distant theorization of historical time. Muratori metaphorically conceives of the city, its neighborhoods, and its architecture, as organisms, in the sense that they are bodies with "tissues" that adapt and change over time in response to crisis and disturbance (see Figure 31.1).

Muratori's death in 1973 coincided with the landmark publication of "Resilience and Stability of Ecological Systems" by C. S. Holling, and an intellectual baton based on notions of crisis, instability, adaption, and change can be retroactively seen as traveling between the two scholars. More recently, Lance H. Gunderson teamed with Holling (2002) to coin the term *panarchy* to describe transformations in human and natural systems and to measure resilience

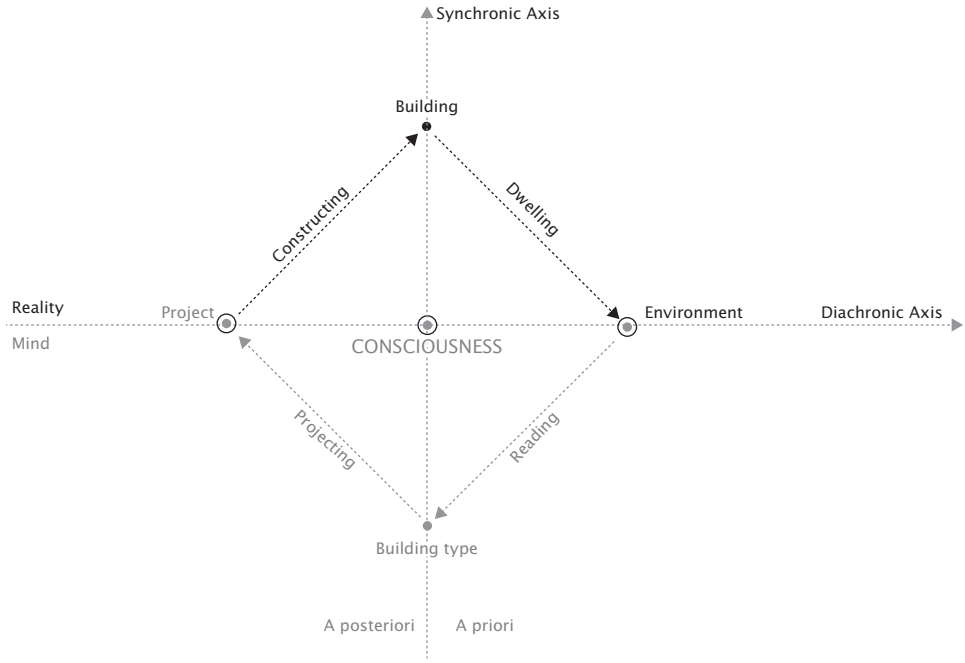

FIGURE 31.1 Muratori's building cycle. In his operative historical studies, Muratori identifies a cycle of the mental reading of the environment preceding a projection of future building, followed by the real construction of buildings and dwelling in settlements, which are, in turn, read and adapted. Adapted from Cataldi (2018).

as a dimension within nested adaptive space and time cycles. These nested scales reflect the systemic approach of Muratori's operative urban histories of neighborhoods, cities, and territories across the millennia. Panarchy establishes an important framework of multiscalar adaptive cycles consisting of phases of exploitation, conservation, release, and reorganization at different scales in space and time. Resilience is described as a "third dimension" through which to measure the expansion and contraction of adaptive cycles. Embodying resilience can be conceived as positioning the human sensorimotor system within operative histories of architecture and built form as a microcosm within the nested scales of panarchy's adaptive cycles in three physical dimensions (see Figure 31.2).

An operative panarchy integrates this continuity of thought between the disciplines of architecture and ecology to develop practices for embodying resilient processes across systems at different nested spatial and temporal scales. In ecology, these scales are described as ranging from the pine needle, to the tree crown, forest patch, and stand to the entire forest biome and regional landscape. These scales represent temporal as well as spatial disturbances from wind and thunderstorms, to fire and infestation, up to climatic forces such as el niño and global climate change itself. The built environment, likewise, is a nested system that ranges from the sensorimotor system of brief and small scales of daily encounters with objects and furniture, to generational change within rooms and buildings, neighborhoods and cities, to civilization upheavals encompassing territorial regions. In this era of the Anthropocene, the entire planet is seen as a human constructed environment confronting a new geological age.

The vast archive of resilience embodied in architecture and built form is supplemented by the innumerable cultural points of view present in the polyglot descriptions of buildings

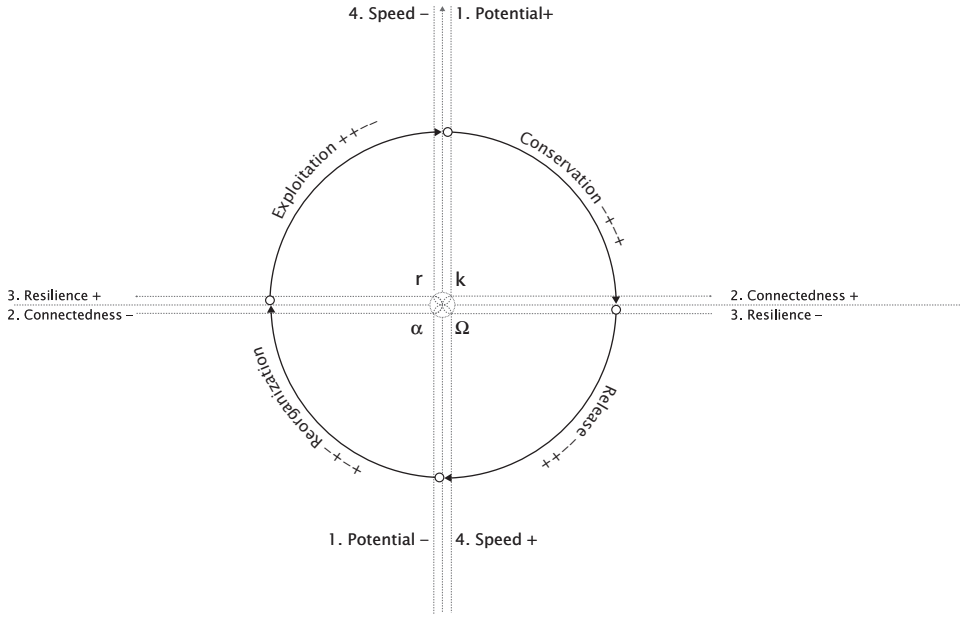

FIGURE 31.2 Adaptive cycle. The adaptive cycle with four variables: potential, connection, resilience. and speed. Adapted from Gunderson and Holling (2002).

and cities in art, literature, and film over time and around the world. Even more potential information is embedded in the living archaeological strata of buildings, cities and rural landscapes as the embodiment of world making, memory, and learning themselves. In the rush to develop contemporary practices that adopt scientific concepts such as resilience, the vast archive of historical evidence for understanding resilience from cultural vantage points is often neglected. As embodied knowledge, architecture and built form provide shared experiences, contexts, forums, and action models situating new pathways for a more inclusive debate concerned with how we collectively inhabit this planet.

Deleuze and Muratori developed their operative histories of cinema and the city in the aftermath of World War II. Likewise, the turn of the 21st century has been marked by critical breakdowns in sensorimotor, social, and ecological systems. Historically, as civilizations grew into territorial empires, vast social organizations developed intricate water, road, and food supply infrastructures along with armies to protect and spiritual beliefs to guide. Contemporary interest in the collapse of these civilizations is further fodder for considering multisystemic resilience given our present predicaments of social inequity and climate change. Embodying resilience through an operative panarchy of architecture and built form recognizes that urbanization is global in scale and climate change often seems distant in time, but that our individual and collective extended sensorimotor systems allows for ethical values and actions to achieve a just transition from an extractive to a regenerative economy here and now. We can look at the growth, shrinkage, and collapse of cities both as part of natural evolution of human learning and adaptation historically and via actions of resiliency in the present moment (see Figure 31.3).

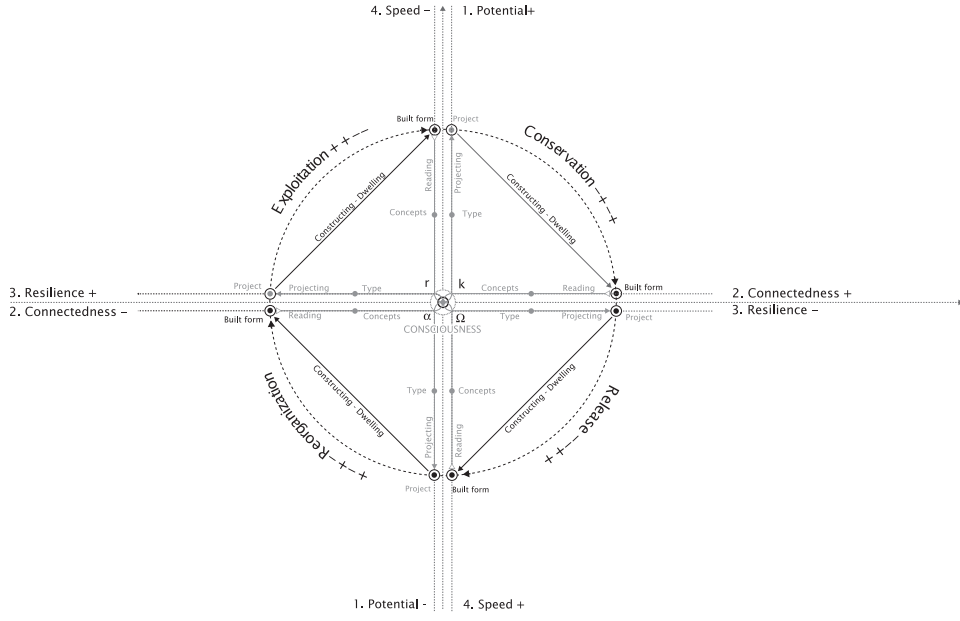

FIGURE 31.3 Adaptive building cycles: synthesis of adaptive and building cycles.

An operative panarchy considers emerging forms of multidisciplinary practices that can consider buildings, neighborhoods and cities as complex adaptive systems, which go through spatially and temporally distributed cycles of growth, crisis, reorganization, and sometimes collapse. In this chapter various scales of multisystemic resilient thinking are presented to develop a working model for analyzing architecture and built form at the intersection of historical and ecosystem studies. An operational panarchy is presented as a process of understanding various nested time and spatial scales from individual bodies structured by daily life worlds within vast regional and global networks of infrastructures of trade and migration over long time frames. Following a literature review of resilience in the built environment, this new hybrid method will be presented by integrating the operational historical method of Muratori and the model of panarchy developed by Gunderson and Holling. Finally, China will be presented as a case study situating and embodying multisystemic resilience within these nested temporal and spatial scales as it incorporates both an operational history of an ancient civilization in relation to the largest and most rapid urban development in the history of the world.

Resilience in the Built Environment

In the following examples, the literature of resilience in the built environment can be understood within three primary paradigms: first, bringing the science of resilience *to* the disciplines of architecture, urban design, and planning; second, integrating ecosystem science *with* architecture and urban design; and third, developing a way to understand the embodied resilience *of* architecture and built form. The first paradigm approaches resilience as a model constructed by scientists and engineers and applied technologically in architecture, urban design, and planning practice. The second paradigm employs resilience as a metaphor that can be shared between the disciplines of architecture and ecology. The third suggests resilience is general knowledge accumulated individually and collectively through trial and error, learning, and memory. As an example of the first paradigm, contemporary practices in the built environment, especially in high seismic or storm risk areas, incorporate resilience thinking from scientific approaches such as the physics of material and engineering resilience (Walker, Salt, & Reid, 2006). The work of the Baltimore Ecosystem Study is presented in the second example, and finally an example of "urban panarchy" from Argentina is presented to introduce the third example.

The first publication of relevance to understanding resilience and architecture is Hassler and Kohler's (2014) edited issue of the journal *Building Research & Information* titled "Resilience in the Built Environment," which focused on the connotative problems with the adoption of the term *resilience* in ecological, psychological, social, social-technical, organizational, and social-ecological systems over the last four decades. The volume is framed by a discussion of the obstacles or constraints for the application of the different meanings of resilience in the planning, design, and operation of the built environment. The editors offer a communication model from ecology that structures multidisciplinary discussions within a discursive framework around common metaphors, such as resilience, versus core definitions based on disciplinary meaning to create working models to operationalize resilience

(Pickett, McGrath, Cadenasso, & Felson, 2014). Hassler and Kohler's introduction argued that resilience-based principles can be applied to the design and long-term management of the built environment in specific areas such as disaster risk management (Bosher, 2014), resilience engineering (Hollnagel, 2014), the institutional management of building stocks, and housing quality (Nicol & Knoepfel, 2014; Pearson, Barnard, Pearce, Kingham, & Howden-Chapman, 2014). Broader themes include a discussion of resilience and cultural notions of time and politics (Moffatt, 2014; Vale, 2014). Moffatt (2014), for example, reflects on how a society thinks about time itself and how the built environment provides continuity for everyday activities and rituals from the past to the future. Vale (2014) articulated the political questions of resilience "To and of what?" and "For whom?" a notion further elaborated by Meerow and Newell (2016) in a subsequent publication.

In sum, Hassler and Kohler (2014) presented multiple physical scales and time horizons of the built environment and explored how the interaction of those different scales creates, maintains, or destroys resilience. Most of the contributions in this special journal issue were more detailed in the description of a specialist understanding of resilience than in the evidence of the built environment itself. Differently scaled urban elements are described as nested systems, mosaics, patches, or assemblages linked by multiple forms of feedback. The soft infrastructure of actors, communities, institutions, rules, governance, and values relate to what the editors refer to as "action arenas." For them, resilience in architecture, urban design, and planning practice has been generally treated as applied technology in relation to natural disasters and climate change, but there is a larger cultural role and meaning revealed in the study of the resilience of buildings and cities as comprising the change and growth to multiple systems under conditions of significant exposure to stress or adversity. The editors find a common shift among the authors in their focus on system breakdown and disorder to recovery, adaptation, or systemwide transformation after exposure to a crisis and the link between the resilience of one system and the resilience of mutually dependent co-occurring systems.

Their introduction briefly acknowledges the resilience *of* architecture and built form as traditional forms of tacit construction knowledge, such as oversizing building components and spaces, redundancy, and reparability. Hassler and Kohler (2014) stated that the urban fabric is a complex sociotechnical system encompassing different scales—building stocks, neighborhoods, cities, and regions—each with different time constants, actors and institutional regimes. They also used the term *built environment* to address the relation between the built and the unbuilt part of the environment, an artifact in an overlapping zone between culture and nature, with causation occurring in both directions. None of the essays in their edited volume, however, addressed embodied forms of resilience that come from understanding the human sensorimotor system in relation to the built environment itself in the face of both social crises and environmental breakdowns (the current volume of papers attempts to address gaps in knowledge such as this; see for example the Chapters 32 and 33).

The second publication of relevance to understanding resilience and built environments is *Resilience in Ecology and Urban Design: Linking Theory and Practice for Sustainable Cities* (Pickett, Cadenasso, & McGrath, 2013), a book that emerged from the 2007 Cary Conference titled "Urban Ecological Heterogeneity and Its Application to Resilient Urban Design." The

publication intersperses chapters from scientists and designers around shared conceptual understandings of the multiple dimensions of resilience: the spatial heterogeneity of cities; the flux of organisms, water, materials, and information in the urban realm; adaptation and change in urban systems; and social actors and agents of urban change. Multiple case studies are presented, and the editors introduce the novel concept of the "metacity" as a way to locate resilience at the intersection of ecology and urban design. In the volume, resilience is defined as a foundation for both urban design and sustainability (Wu & Wu, 2013), but it is described as a dynamic and often unstable one. Key concepts of resilience in ecology that are related to urban design include multiple stable states, thresholds and regime shifts, specified and general resilience, complex adaptive systems, and panarchy. Cities are presented as nested adaptive cycles at characteristic scales in space and time. Examples of crisis in adaptive cycles include protest or revolt, urban development and its myriad of processes and institutions and levels, economic recessions, and climate change. Cross-scale dynamics of urban systems can induce phenomena that are difficult to predict, but that can be prepared for. Capacities for urban transformation, such as the capacity to overcome the obstacles of an undesirable regime to create a fundamentally new system, include connectedness, modularity, and tight feedback loops.

Concurrent with the Cary Conference, Pickett, Cadenasso, and Grove (2003) presented "resilient cities" as a metaphor for integrating ecological, socioeconomic, and planning realms. For science, metaphors are slippery figures of speech that yet have explanatory power for interdisciplinary discussion and can spur creativity around common conceptions and visions. The authors argue, however, that metaphors must be followed with the realization that terms will have different meanings across disciplines and descriptive models must be employed to make metaphors operative in real situations. Resilience is proposed as an integrative metaphor to establish links between the new nonequilibrium paradigm of ecosystem science with the dynamics of the architecture, design, and planning of cities. They argued that this new paradigm is more inclusive and open and acknowledges that ecosystems may be externally regulated; may have multiple, or no, stable state(s); and have probabilistic dynamics and disturbance. Their essay concludes with a formulation of tactics to promote resilience in the nonequilibrium sense in ecology, planning, and design: spatial heterogeneity, linked concern of structure, function or process, and temporal changes that can be exploited through watershed, patch dynamics, and human ecosystem frameworks. Human perception, actions, reflection, and learning are a part of the human ecosystem "learning loop" where dialogue and co-production of research and design choices can have ecological consequences that can be measured and communicated.

Pickett, Cadenasso, and Grove's (2003) essay grew out of a National Science Foundation program that began funding long-term ecological research in two urban areas in the United States beginning in 1997—Central Arizona–Phoenix (CAP) and the Baltimore Ecosystem Study (BES). This new approach redirected the science of urban ecology away from focusing on green spaces *in* the city to establish an ecology *of* the city as a whole (McGrath, 2018; Pickett et al., 2013). From 2002 to 2005, architecture and urban design faculty and students worked in collaboration with the BES through academic project-based design research, in essence, operationalizing patch dynamics (Cadenasso, 2013; Cadenasso, Pickett, McGrath,

& Marshall, 2013; McGrath et al., 2007; Pickett & Cadenasso, 2007). Student design projects were evaluated within the discursive traditions and research culture of ecology as the scientific study of the distribution of organisms in space, their relation to environment, and the flows and feedbacks between organisms and their environment.

The designers working with BES developed a notion of resilient practices and interconnected social-natural relations (Marshall, McGrath, & Towers, 2007). Diagrams were important design tools for translating scientific concepts, such as the dynamics between environmental and cognitive factors (Van der Leeuw & Aschan-Leygonie, 2005). Designs were seen as a way to improve resilience by providing cognitive experiences in the built environment that allowed for social dynamics to adapt to the speed and frequency of environmental change. The authors describe this as a socially adaptive transformation of design practice itself. The concluding chapter in the book "Designing Patch Dynamics" (McGrath et al., 2007) discusses positioning urban designs around community-based models of patch dynamics, not in just the scientific sense as a description of a system's structure and function but in an inclusive design sense as speculative idea or mental image of an object or form, which can be collectively initiated (McGrath, 2007). The essay correlates Paul Krugman's self-organization of the economy in space (1996) with Simon Leven's (1999) description of complex adaptive system and building resilience through the reduction of uncertainty by monitoring, spreading risks and forming groups, the expectation of surprise by adaptively managing, by building flexible response systems, maintaining heterogeneity, sustaining modularity, preserving redundancy, and tightening feedback loops, all qualities that are evident in the history of architecture and built form.

The third publication of significance to this discussion of resilience in the built environment is by Garcia and Vale (2017) who provide more direct evidence of the role architecture and the built form play in sustaining resilience in their book *Unraveling Sustainability and Resilience in the Built Environment*. Their description of resilience not only follows a familiar trajectory from early definitions in engineering related to mechanics of materials and elasticity (19th century) to Holling's (1973) description of resilience in ecology but also touches on resilience in behavioral science and environmental psychology. However, it is the authors' embrace of what they refer to as "building an urban panarchy" around adaptive cycles where "the built environment as a house sits in a neighborhood, which sits in the city, which sits in a landscape, which sits in a hydrological cycle, and so on" (Garcia & Vale, 2017, p. 52), which is, potentially, the most influential part of their argument.

Garcia and Vale (2017) provide the case study of San Miguel de Tuduman in Argentina to support their notion of urban panarchy because of its transformation from a colonial, liberal metropolis to a contemporary "borderless" city. For them, urban heritage is not conservation through old buildings but instead the continuous spatial pattern of streets, blocks, and plots and the evolution and emergence of new building types within the persistence of the urban identity. San Miguel de Tuduman's extended colonial grid remained the same through the modern development of the city center with the connection of the railway and plot subdivisions and building footprints - "sausage" types of housing within the long and thin blocks. In a context like this, change happens in long and short durations, and at big and small scales. Because of rules governing change, which allowed blocks and plots in the city center

to be maintained beyond more than one cycle, the case of San Miguel de Tuduman is an example of how the resilience *of* the built environment can be measured over time. Building an urban panarchy, for the authors, involved the generation of timelines of major events and perturbances within urban histories.

Ecological resilience offers Garcia and Vale (2017) a comprehensive, systemic and methodological way of linking key concepts that are familiar to architects: complex systems, scales, diversity, connectivity, redundancy. "The idea of understanding the urban landscape of cities as an urban panarchy could be promising for both managers and designers. The adaptive cycle, panarchy and the idea of multiple stability states are all theoretical instruments with which to assess the quality and quantity of change of a system" (p. 53). They suggest that urban databases can be combined with the question of where you are in the cycle. The authors recognize that the integration and visualization of the behavior and performance of a system at multiple scales at the same time leads to a big change in urban analysis as both bottom–up and top–down forces are acknowledged. Urban panarchies introduce nonlinear dynamics into urban thinking and provide a rich context for novelty and creativity for designers and citizens alike. Their urban panarchy provides a way to look at crisis or collapse as an opportunity. The next section explores this topic in greater depth by introducing a multisystemic understanding of built form through Saverio Muratori and his notions of civic consciousness understood through operative history.

The Resilience of Architecture and Built Form

In the context of the European crisis following the destruction caused by World War II, Italian architect Saverio Muratori conducted a series of studies at successively larger scales for an "operative history" of buildings, neighborhoods, cities, and their surrounding territory (1960; Muratori, Bollati, Bollati, & Marinucci, 1963, 1967, 1973). The crisis, for Muratori, was not only the devastation from the war, but the sensorimotor disruption of modernity, which interrupted the continuous spontaneous tradition of city building that prevailed from antiquity to the enlightenment. As mentioned in the opening reference to neorealist cinema, centuries-old bodily habits, social behaviors, and individual thoughts no longer made sense. For Muratori, building is not just the assembly of inert construction materials, but a living act embodying human memory, values, and actions relating to a common, universal experience and understanding of nature as the basis for life (Tagliazucchi, 2014, 2015). In the moment of crisis in the postwar city, Muratori recognized what he referred to as a loss in an organic spontaneous civic consciousness. Civic consciouness can be maintained between historic phases of crises, where city dwellers/builders construct and adapt the cities they inherit over time without needing or requiring mediation or choice (Caniggia & Maffei, 2001). Muratori's history is an activation of a collective body of hereditary knowledge to uncover and remember a lost civic consciousness and to make it operative in the face of contemporary challenges. Urban form, structure, and function are organic aggregations of the learning, memory, decision-making, and actions that produce buildings and open spaces within nested scales of what is referred to as urban tissue or fabric, "special organisms" within the city, the city metaphorically as an organism itself, and regional territory as the human imprint on nature.

The hybrid concept of an operative panarchy links Muratori's concept of a working, activated history of civic consciousness in architecture and built form with Gunderson and Holling's nested panarchy framework for resilience. An operative panarchy comprises a multisystemic understanding of human resilience in the face of crises within cycles of historic and ecosystem transformation in the built environment. The term *panarchy* was adopted during the multidisciplinary meetings of the Resilience Alliance, which were seeking a cross-scale, interdisciplinary, and dynamic theory of adaptive change (Gunderson & Holling, 2002). The concept was developed as an integrative theory to help in the understanding of interrelated economic, ecological, social, and evolutionary changes occurring globally. Based on Holling's description of resilience and instability in ecological systems, members of the Alliance used the name of the unpredictable Greek god Pan to capture the interplay between change and persistence and between the predictable and unpredictable. Previously, Belgian journalist Paul-Emile de Puydt (1860) coined the term *panarchy* to describe a political utopia where individuals could freely choose from alternative forms of government without physically moving. De Puydt imagined a shifting mosaic of political allegiances not aligned to the geography of a nation state. An operative panarchy here specifically refers not only to the nested spatial and temporal scales of adaptive ecosystem cycles, but also conjures the radically decentered political system proposed by de Puydt (1860) (see Figure 31.4).

Like Muratori before them, Gunderson and Holling were interested in the interactions between people and nature as examples of social and environmental responsiveness and learning. In addition to examining the patterns of change at multiple scales, panarchy also suggests an analysis of the variable temporalities of change in ecological, social, and cultural systems. They argue that panarchy frees us from the trap of the expert where agencies become rigid and lose a sense of the larger whole in trying to solve immediate problems of the parts. An operative panarchy extends Muratori's method, based in the political, economic, and cultural history embodied in the architecture of the city, to ecosystem science. Through

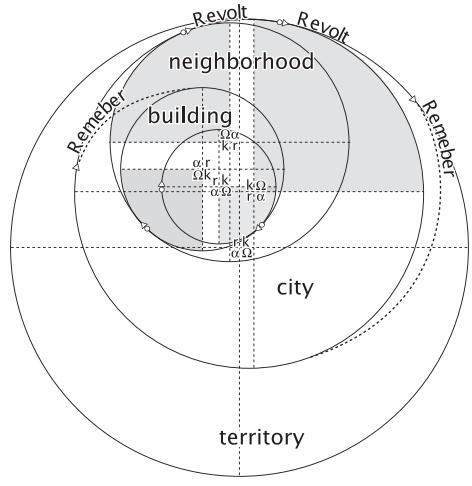

FIGURE 31.4 An operative panarchy. The shaded areas depict the phase of an adaptive cycle. A new cycle is created either by a revolt effect to a higher scale, or a remembering event to a lower scale.

an operative panarchy we can sense and read cities and territories as the result of the interactions between slow/large and fast/small moving processes and collectively govern them as nonlinear alternating states of stability and change (Gunderson & Holling, 2002). Operative historical analyses of architecture and built form embody concepts of multisystemic resilience and reveal how decisive actions made by individuals give rise to emergent features of communities and societies. An operative panarchy categorizes different scales of architecture and built form within different time cycles to stress the importance of sensing, reading, and interpreting building as a progressive, open, and inclusive system. Furthermore, it places the researcher as part of a community within the physical evidence of adaptive cycles where an embodied collective understanding of the past through an analysis of the present reality leads to a better and more resilient future.

As a critical start to his way of thinking, *Studies for an Operative Urban History of Venice* (Muratori, 1960) was the result of 10-year pedagogical project began in 1950 when Muratori became professor of Distributive Characteristics of Architecture at the University of Venice. His objective was to redirect architectural teaching away from the abstract technical lessons of modernism and toward the direct observation of human life and decision-making embodied in the distributive pattern of Venice's historical city fabric. Beginning with a close study of a single neighborhood, Muratori and his team of students identified simple changes in building construction as a method of studying the dynamics of architectural reality "from life," much like a plant ecologist's direct study of the structure of nature. The focus of their studies was a room by room survey of selected buildings and critical historical reconstructions of entire neighborhoods. The research identified phases in the continual construction process and evolution of Venice's historic building fabric separated by what are referred to as crises, taking advantage of the "precious field experiment" (p. 5) offered by the living laboratory of the city itself. Individual, anonymous building types were studied both in their own line of development and stratification, but also as part of what was referred to as the city's "tissue," which in turn comprised, for them, the urban "organism" grasped only in its historical dimension. Today we can understand that Muratori was describing the city as a complex adaptive system, and the organism in question are human agents constructing their habitat individually and collectively through sensation, experimentation, learning, remembering, and feedback (see Figure 31.5).

The seeming inert permanence of buildings belies the fact that cities grow, shrink, change, and adapt continuously over time and any new construction is a consequential response to the conditions set by the past. Surveys and reconstruction drawings were just the first step in Muratori's (1960) efforts to interpret the "irrepressible individuality of historical vision, actuality, intentionality and then the appropriate adaptation practice" (p. 5). Through an operative practice, the history of a city like Venice, Muratori's focus, was understood as constituting an ethical, social, and civil cultural heritage. Construction layers in different parts of the city revealed different phases in development of Venice's civic consciousness. The remote lagoon island of Burano was studied to discern the original process of constructing an "archipelago city" of fortified enclaves within the lagoon. Various remote neighborhoods revealed different phases in the evolutionary process of the transformation of the city's fabric. The study identified a new political economy that emerged to create the mature version of

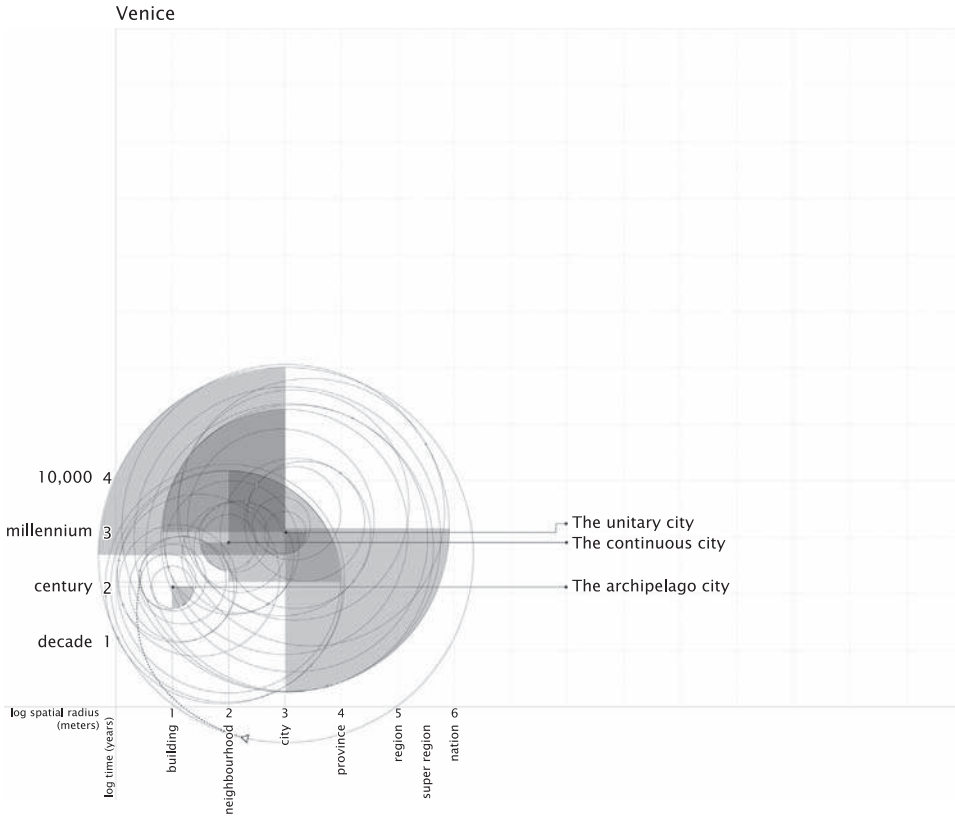

FIGURE 31.5 Venice panarchy: diagram of the adaptive cycles described in Muratori's history of Venice. The centers of the circles are located on time and space scales.

the "unitary city" that is evident today in public promenades connecting the neighborhoods around Venice's commercial center near the Rialto bridge to the religious and political center of San Marco. Muratori's study of the changing neighborhood dynamics of Venice demonstrated both the construction methods for the initial fortified inhabitation of the lagoon, followed by Byzantine and Gothic phases of reconstruction around a network of islands and canals, and the later mature development of an open and unified pedestrian and public space network after the Renaissance.

In contrast, Muratori's operative history of Rome (1963) demonstrated the longer and more dramatic adaptive cycle of civilization as he traced four phases from the origins of the city as fortified villages occupying the city's famous seven hills overlooking a crossing at the Tiber River, through their unification during the Republican age around the Forum, to extensive monumental development at the height of the empire, and its shrinkage following collapse (see Figure 31.6). Most interesting in the case of Rome, reorganization and regrowth of the city following imperial collapse occurred within its ruins. Muratori and his team of researchers created an atlas of four folios that systematically catalogued changes to routes and pathways, civic and commercial nodes, neighborhood tissue or fabric, and what he metaphorically called "special organisms," that were new building types developed to serve public

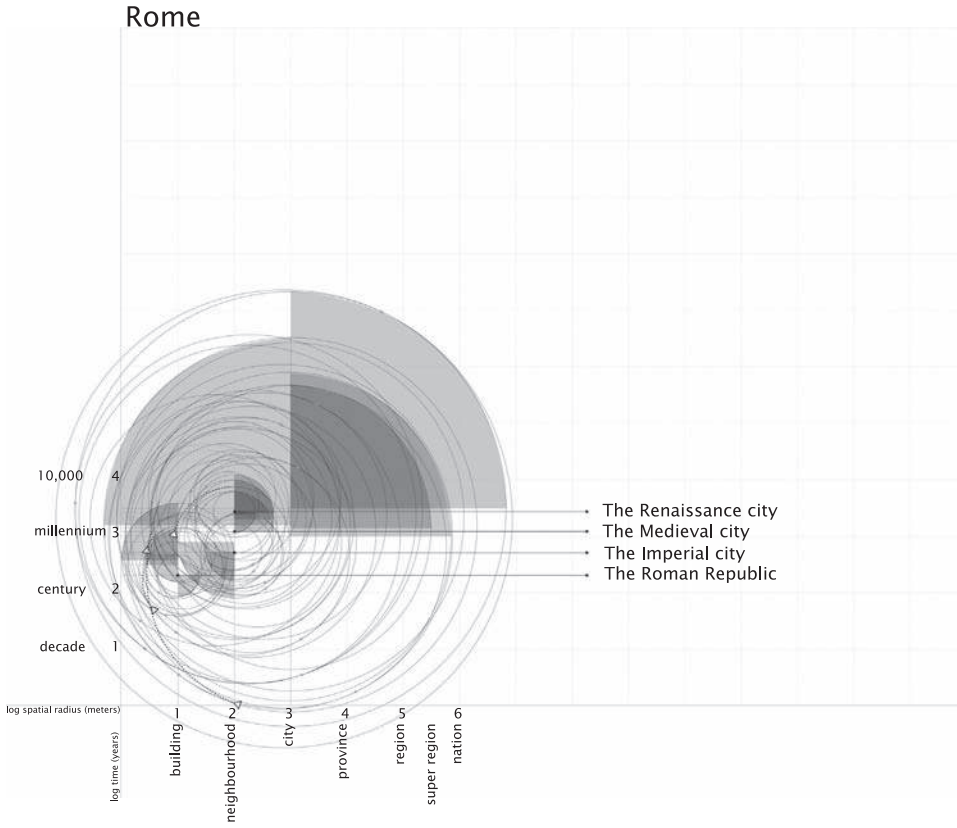

FIGURE 31.6 Rome panarchy: diagram of the adaptive cycles described in Muratori's history of Rome.

and institutional needs during the four different time periods. Through his study of Rome, Muratori presented the case that architecture and built form embody a practice of civic consciousness, what we might now call multisystemic resilience, even in the face of catastrophic political and economic collapse. This study of the city of Rome overlapped with his larger unfinished final project of a comparative operative history of global civilizations and territories, including India and China, which remains especially relevant today. Noticeably absent from Muratori's histories of Venice and Rome, however, is a discussion of great buildings or famous architects. Instead his operative history focuses on the anonymous actors who construct the ordinary city and collectively transform it through economic crisis and political shifts.

An Operative Panarchy

Like Muratori's multidimensional building operations, Gunderson and Holling (2002) describe resilience as a dimension within what ecosystem science describes as the adaptive cycle. However, Muratori provides a clearer definition of embodied human consciousness, agency, and choice in successional dynamics that Gunderson and Holling often describe as

self-organized. Each level in Gunderson and Holling's nested panarchy contributes small amounts of information and materials to the next. Muratori's examples demonstrate how human societies develop meaning and myths, rules, and norms about the allocation of resources and labor. A panarchy, according to Gunderson and Holling, is both creative and conserving as a whole, and resilience is the capacity to create, test, and maintain this adaptive capability. The spatial patterns of panarchies form patterns, mosaics, and patches of different-sized resource aggregations at different scales, with lumps and gaps generated from biological diversity. These patterns are evident in Muratori's carefully delineated maps of Venice and Rome and in his initial territorial sketches for Europe, India, and China. In organisms, rules become genetically encoded and guide instinctive behaviors. Human rules, schemas, and scripts become encoded in behavior, myths, and rituals gathered, stored, and remembered in cultural clusters (Gunderson and Holling, 2002) that Muratori depicts as neighborhood tissues, city organisms, and territories.

The hybrid concept of an operative panarchy derived from Muratori and Gunderson and Holling can be used to examine how buildings, neighborhoods, cities, and territories metaphorically "learn" over time (Brand, 1994). This learning happens within single individual life spans, reflected in changes to the built and open space units of land and property, as well as slowly changing over many generations in institutions and public spaces. Slow cycles of urban growth and human learning are disrupted by rapid phases of reorganization and revolt, where for short periods of time, novelty can emerge in the face of disturbance or crisis. In *Transparent Cities* (McGrath, 1994), for example, the historical recycling of the urban fabric of Rome was compared to mapping Manhattan as an archaeological site of the operations of capital. While Rome demonstrates the historical imperial, medieval and modern phases of its history, New York's urban change can be seen as successively structured by mercantile, industrial, and financial capital. In the online interactive website Manhattan Timeformations (The Skyscraper Museum, 2019), this urban archaeology was extended through three-dimensional digital modeling and the interactive user interface of a computer to explore the emergence of both the skyscraper as a building type, and the evolution of Manhattan's two business districts. Initiated by a timeline that charted the cycles of real estate booms and busts, the digital model extrudes that timeline as the third, vertical dimension in the computer-generated model. Toggling through space and time, a viewer can understand how the economic busts of the Great Depression in the 1930a and the Oil Crisis in the 1970s resulted in technological novelty in the subsequent phases of skyscraper development: the glass curtain wall, fluorescent lighting, and air conditioning in the building boom after World War II, and the use of computers in workspaces in the reorganization of the economy in the 1980s.

The Embodied Resilience of Architecture and Built Form in China

Satellites, GPS, and digital hand-held devices have extended our human sensorimotor reach. We sense the city remotely as well as close-up (McGrath & Shane, 2005). Global positioning

technology traces our daily activities within a vast archive of spatial and temporal information of our journeys through an operative urban panarchy. An example may stretch from a rice farming village measuring water pollution on the outskirts of Shanghai, to the map of lowland rice cultivation in the major rice growing countries of Asia prepared by the International Rice Research Institute (Nelson & Gumma, 2015; see Figure 31.7). Lowland wet rice cultivation is the cradle of the civilizations of South, East, and Southeast Asia. The impact of colonization, independence, and the global extension of neoliberalism across Asia are three relatively recent crises and phases that have shaped a surge in urbanization, the shocking extent of which is most visceral in the data set of nighttime lights as indicator of urbanization (NASA, 2017). When we turn on our lights, our presence is registered by this constantly updated database. The superposition of these two data sets produces a striking portrait of panarchy, territory, civilization, and the planetary urban crises, as well as a framework to fulfill Muratori's operative history of territory through Gunderson and Holling's panarchy. Given access to the tools and enabling forms of governance, there is a remarkable agility of the human sensorimotor system to adapt to an often-uncertain world that passes by and surrounds us.

To illustrate, at the turn of the millennium, millions of residents of the cities of China experienced sensorimotor breakdowns similar to those experienced in postwar Europe.

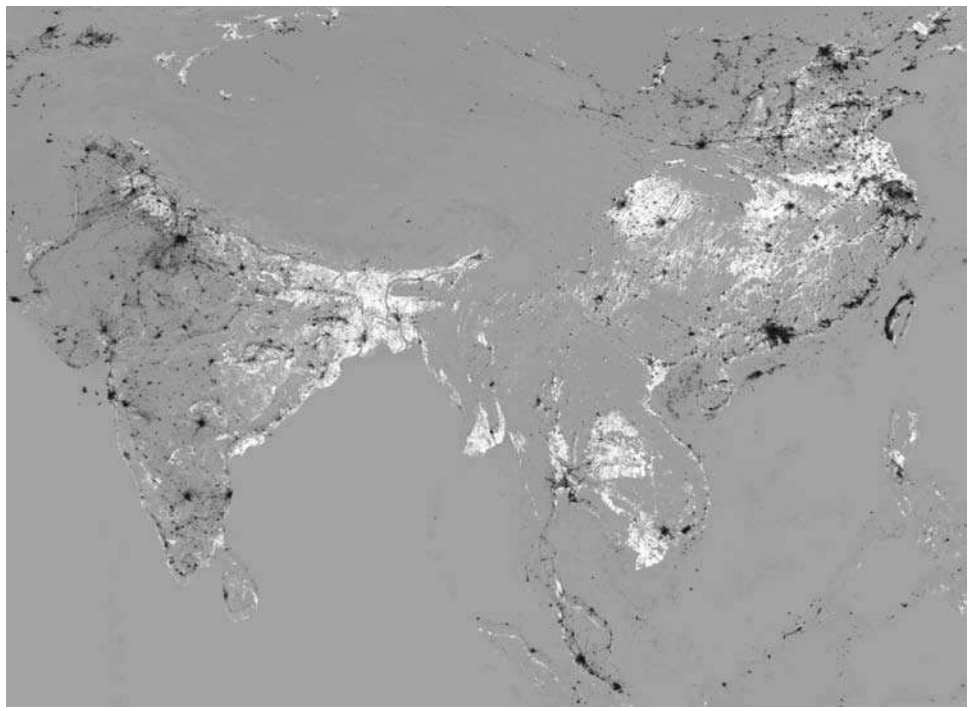

FIGURE 31.7 Asia map. This superposition of Nelson and Gumma's data of lowland rice cultivation in Asia with NOAH's nighttime lights imagery shows the explosive growth in Asia's cities on landscapes created by hand over multiple millennia.

Thousands of years of Chinese architecture and built form were suddenly transformed beyond recognition following the largest and most rapid urban transformation in the history of the world. An operative panarchy of architecture and built form in China, based both on remote-sensing and historical inquiry, can provide physical and theoretical evidence to reveal the ideals and processes of constructing buildings and cities over the millennia in relation to the goals of embodying multisystemic resilience (see Figure 31.8). As has been established, cities and buildings are complex adaptive systems based on the social organization of human organisms in relationship to territorial transformation. Furthermore, the human organism is equipped with a sensorimotor apparatus that allows for circuits of learning, remembering, and innovating. China presents a considerable challenge in testing the operative panarchy model of architecture and built form based on Muratori's unfinished operative history of territory. China contains the longest continuous tradition of built form historically constructed without the presence of the profession of architecture. The craftsmen and builders were the architects of ancient China embodying the collective consciousness of construction knowledge. This history, if operationalized, could provide further evidence of Muratori's argument about the spontaneous civil consciousness of the anonymous architecture of the city.

Uniquely, China established a collective building system that, until the fall of the Qing dynasty in 1911, had been imperially legislated, governed by bureaucrats and constructed by craftsmen according to long established handbooks and such as the *Yingzao Fashi,* which dates from the early 12th century (Steinhardt, 2014) although the territory was invaded and occupied by non-Chinese at several times. Steinhardt notes that Western self-consciousness in innovation in design had no place in the evolution of China's ancient building system.

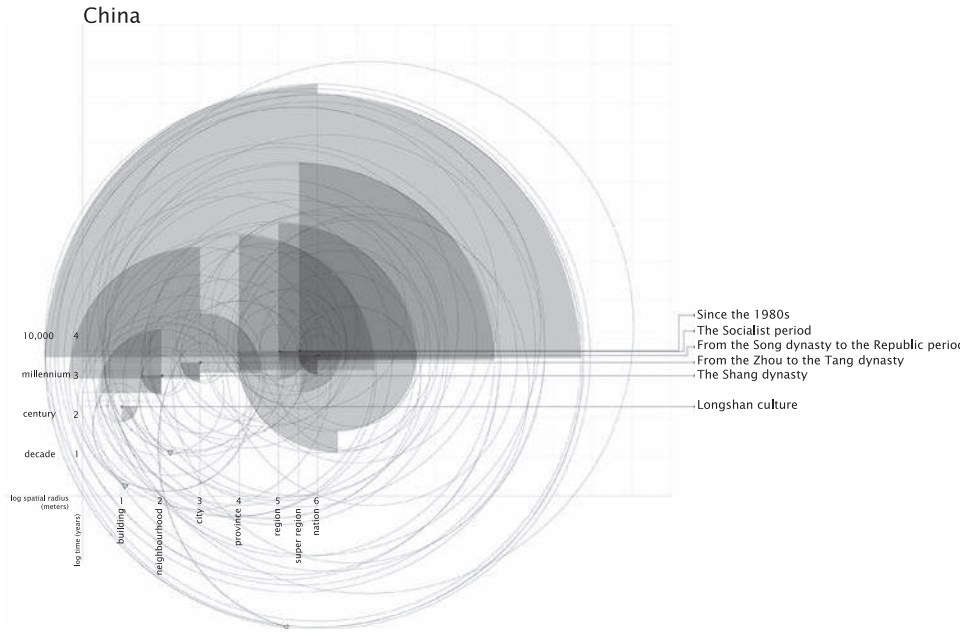

FIGURE 31.8 China panarchy: diagram of the adaptive building cycles in Chinese history.

There were no schools in which to study architecture in China until the third decade of the 20th century when the first generation of architects returned from study abroad and set out to establish a history of Chinese architecture (Steinhardt, 2014). They quickly organized schools of architecture and began to examine historical treatises and local records across the country in what Muratori would identify as the basis of an operative history. The elite first generation of architects broke with social taboos of the imperial system and explored China's countryside and engaged with the local villagers to uncover and survey old buildings, many of which were lost in the wars and upheavals of the 1940s and the Cultural Revolution from 1966 to 1976. The establishment of this slow and measured work in cities and villages across the country today is constantly hindered by urban modernization and the rural improvement movement. China continues to seek rapid economic and technological modernization, which makes it far more difficult to reconnect recent development booms to long building tradition and culture.

As Chinese architectural historian Fu Xinian (1984) argues, Chinese buildings are not merely artifacts invented by human creativity according to different geographical and climatic conditions but are also an enduring and continuous system generated across the civilization's vast territory over several millennia of innovation and synthesis. Steinhardt (2014) describes the defining feature of Chinese architecture as its recognizable identity based on many shared features that is unchanged by purpose, location, or time period of construction. These shared features include an architectural complex of interrelated buildings, courtyards, and enclosing arcades organized within a horizontal axial space enclosed within a walled rectangle extending through gates in the four cardinal directions, with one main building at the center. A modular and flexible timber post and beam system with glazed tile roofs indicates a building occupant's rank. This use of architecture and built form as a lexicon of culture and status was reproduced and persisted as a powerful symbol of Chinese civic consciousness across time and space. This tradition aligns with Muratori's argument about buildings and cities as archetypes and as part of a collective memory. But the physical evidence defies his methods of chronological classification of building cycles, as the same architectural language was continuously repeated across the world outside of his classification system of discernable temporal phases in Europe (Steinhardt, 2014).

Although there had been a significant decline in traditional urban tissue and landscape during the Republican Era (1911–1949), Gaubatz (1998) points out the continuity of key landscape elements in different eras of Chinese urban history before the 20th century. In socialist China (1950–1978), a new link between building tradition and territorial civilization was set up in through a predominant type of work unit—danwei. The intention of building the danwei system had been heavily inspired by the former Soviet Union, however, the built form of the danwei is actually a variant of the walled wards of early traditional Chinese cities (Gaubatz, 1995). The development policy since the Cultural Revolution (1966–1976) emphasized rural development and the role of small and medium-sized traditional cities. The old administrative cities had been gradually transformed into a hierarchical urban network of local work units of industrial and agricultural production centers. Subsequently, there has been an accelerated erasure of historical Chinese cities and buildings since 1979 when China first introduced the newly created city of Shenzhen, and later transformed every major city

according to a national program of rapid urbanization at a huge scale. Since the top-down emphasis on urbanization in the 1980s, the unprecedented construction behavior has led to a fundamental transformation of the country's character at all scales from buildings to cities, which is highly visible in the spectacular landscapes of megablocks encompassing urban villages and enormous gated developments of superblock dwellings.

Four recent publications point the way to an operative panarchy of architecture and built form in China. In 2010, McGrath wrote about the recent ambition of creating "Silicon Valley in Paradise" in Hangzhou, the ancient capital of the Southern Song Dynasty (McGrath, 2010). The city continues to embrace the lush public landscape of West Lake, a former scenic imperial enclave celebrated in poetry and painting for centuries, now the most visited domestic tourist spot in China. Likewise, Sharon Haar and Victoria Marshall (2012) recognize the impact of Chinese urbanization on the ecology of the "megadeltas" of China and point to solutions involving remote sensing and local feedback. Pickett and Zhou (2015) describe the territorial analysis of the Chinese "megaregion" as a new phase in urbanization following the city, metropolis, and megalopolis. Using remote satellite data, they are able to track the last 30 years of urbanization in Chinese cities as part of what they refer to a global urban continuum. David G. Shane (2015) explores Chinese "metacities" as digitally enhanced information systems. This interlinking between the social and ecological "crisis" of rapid and large-scale urbanization in China coincides with both the spread of digitally enhanced communication and information systems across the planet and a growing realization of the limits of the planet's natural carrying capacity. Combining historical inquiry with theories of ecosystem change, these authors have begun the theoretical work of recognizing the importance of embodying multisystemic resilience at the nested scales of an operational panarchy of China's megaregional territories.

Conclusion

Karl Kropf (2008) refers to Muratori's notion of crisis as both present in the mental state of involved humans and something pervasive across society. The perceived crisis today includes the feelings and thinking that have arisen in response to rapid urbanization, global warming, resource scarcity, pervasive inequality, and a global pandemic. Kropf locates Muratori's notion of crisis within a spiraling sequence of human life: crisis–response–habit–crisis–response–habit, a coarse grain version of Deleuze's human sensorimotor system. Our sensorimotor apparatus responds to difference and is disrupted by chance, variability, and diversity. Different kinds and scales of crisis contribute to different cognitive states of mind, producing resilient responses later ingrained in habits. Kropf lists stories, religion, music, visual art, the sciences, technology, and, of course, architecture and urbanism as cultural responses to this sense of overcoming crises and of overcoming sensorimotor breakdowns, the embodiment of resilience.

In related writing on the sensorimotor system, Henri Bergson (1896/1991) describes our human consciousness as split in two: there is the actor playing our role in the arenas of life, and the split self, watching as if floating above the scene. This dual sensibility is the

primary question of embodying multisystemic resilience: How can we act as sentient, ethical, embodied beings in our daily lives, while having a reflective civic consciousness of the consequences our acts, above and beyond them at a planetary scale? The metacity was introduced as a concept linking this split consciousness to architecture and urban ecology to develop the cognitive capacity to become more resilient as individuals, social groups and a species in the face of the unprecedented challenges we face globally (McGrath & Pickett, 2011; McGrath & Shane, 2005). The concept resonates with new urban forms and ways of life ushered in since the introduction of the internet as a way of enabling new understandings of the heterogeneity and dynamics of both ecological and social systems. Metacities are not only nested panarchical phenomena that transform at different spatial and temporal scales (Pickett et al., 2013) but are also connected globally through shared concerns around social injustice and climate change and the ability to communicate distantly through the internet. De Puydt's (1860) political panarchy conceives of distributed governance systems, which parallel the basis of the metacity in ecological theories of metacommunity and metapopulation. Metacities are the embodiment of our digitally extended sensorimotor resilience and can also be seen within resilient panarchical governance system. Therefore, the metacity as a theoretical model and a set of principles can guide future study of an operative panarchy of embodied multisystemic resilience globally.

An operative panarchy of the metacity provides a way to respond to our current crisis through the recognition of the embodied multisystemic resilience *of* architecture and built form. An extended sensorimotor system engages cultural and scientific representation and communication through digital technologies, remote-sensing, and data-rich handheld devices. Multisystemic resilience in architecture and urban design is conceived, represented, and communicated through a civic consciousness as well as embodied and lived. A structure for responsive change that scales from architectural and urban systems begins with the sensing human body. By operationalizing panarchy, nested ecosystem scales are seen in both short and long-term durational frameworks. The human sensorimotor system is extended through the ubiquitous integration of deep data drawn from satellites, grounded instruments and handheld devices. The seamless location and spatialization of data and information exponentially increase our ability to assess, measure, and study the resilience of multiple systems of built form across scales and over time (McGrath & Shane 2005) and to collectively act on the basis of this extensive access. For all these reasons, developing an embodied understanding of multisystemic resilience, linked by an extensive and collective global sensorimotor system can help guide the future health of individuals, communities, and the planet itself through the embodiment of an operative panarchy of architecture and built form.

Key Messages

1. This chapter introduces an embodied approach to multisystemic resilience through an understanding of architecture and built form as the physical evidence of complex adaptive social-natural systems over time. Current approaches to resilience in the built environment respond to specific, immediate, and projected threats rather than a more

fundamental and universal knowledge of multisystemic resilience in architecture and built form.

2. A brief overview of the literature on resilience in the built environment demonstrates the limits of a technical focus of resilience in the professional disciplines of architecture, urban design and planning. Three recent publications are discussed that cover a broad range of applied resilience in architecture, urban design and planning, resilience as a metaphor to link ecology and urban design, and an architecturally based typomorphological basis of resilience in the built environment.
3. The hybrid concept of operative panarchy is introduced linking Saverio Muratori's concept of an operational history of architecture, city, and territory and Lance H. Gunderson and C. S. Holling's panarchy framework of human adaptation and ecosystem transformation. This hybrid concept forms the basis for establishing an array of spatial and temporal scales in which to embody multisystemic resilience in the physical reality of the built environment.
4. Following on the case study of urbanization in China, speculations on the metacity as a framework to establish a politically operative panarchy is presented. The metacity is both a set of principles and an array of models for action that can guide multisystemic resilience research through technological extensions of the human sensorimotor system.

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