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Building Cities That Think like Planets

IF OUR CITIES ARE TO BE RESILIENT ON A PLANETARY TIME SCALE, WE must expand our horizons of time and space as well as our ability to embrace change. Earth has evolved into a living planet over a billion years, allowing human life to emerge. How can thinking on a planetary scale help us understand the place of humans in the evolution of Earth and guide us in building a human habitat of the "long now"? This chapter discusses the implications of complexity and uncertainty for building the cities of the future, and it articulates pathways and principles for urban design and planning.

Cities face an important challenge: they must rethink themselves in the context of planetary change. Urban ecologists must understand the role that cities play in the evolution of Earth. Can the emergence and rapid expansion of cities across the globe represent a turning point in the life of our planet on a scale similar to that of the Great Oxidation (Lenton and Williams 2013)? And can the patterns of urbanization determine the probability of crossing thresholds that will trigger a planetary shift of the same magnitude and significance? I do not answer these questions. Only a new extraordinary collaboration among urban ecologists, evolutionary biologists, and other natural and social scientists might do so. I suggest that we begin to define a series of hypotheses and develop long-term studies that can tackle such questions in new and productive ways. We must also rethink the research infrastructure necessary to support diverse networks of scientific teams.

In this book, I have advanced the hypothesis that cities are hybrid ecosystems: they are unstable and at the same time able to change and innovate. I proposed a co-evolutionary paradigm for building a science of cities that "think like planets," a view that focuses on both unpredictable dynamics and experimental learning. I have elaborated on some concepts and principles of design and planning that emerge from such a perspective: self-organization, heterogeneity, modularity, cross-scale interactions, feedbacks, and transformation. In closing, I pose a question: how can thinking on a planetary scale help us to understand the place of humans in the evolution of Earth and guide us in building a human habitat of the long now?

Planetary Scales

Humans make decisions at multiple scales of time and space simultaneously, depending on how they perceive the scale of a given problem and the scale of influence that their decisions might have. Yet it is unlikely that the scale extends beyond one generation or includes the entire globe. The human experience of space and time has profound implications for our understanding of world phenomena and for making long- and short-term decisions. In his book *What Time Is This Place?*, Kevin Lynch (1972) eloquently told us that time is embedded in the physical world that we inhabit and build. Cities reflect our experience of time, and the way we experience time affects the way we view and change the environment. Thus our experience of time plays a crucial role in whether we succeed in managing environmental change. If we are to think like a planet, we must deal with scales and events that are far removed from everyday human experience. Earth is 4.6 billion years old. That's a big number to even conceptualize, much less incorporate meaningfully into our individual and collective decisions.

Thinking like a planet implies expanding the temporal and spatial scales of city design and planning, but not simply from local to global and from a few decades to a few centuries. Instead we must include a broad range of scales, from the human experience of place (Beatley 2010) and the landscape ecology of regions (Forman 2008) to the scale of geological and biological processes operating on the planet (Alberti 2014). Thinking on a planetary scale also requires expanding the idea of change. Lynch (1972: 1) reminded us that "the arguments of planning all come down to the management of change."

But what is change? Human experience of change is often confined to fluctuations within a relatively stable domain. However, Planet Earth has displayed rare but abrupt changes and regime shifts in the past (e.g., the last glacial-interglacial transition). Human experience of such change is limited to marked changes in regional system dynamics, such as altered fire regimes and extinctions of species. Yet since the Industrial Revolution, humans have been pushing the planet outside the domain of stability that it has occupied since the beginning of human history. Will human activities trigger a dramatic global event comparable to those experiences by Planet Earth? We can't answer that, as we don't understand enough about how regime shifts propagate across scales, but emerging evidence does suggest that if we continue to disrupt ecosystems and the climate, we face an increasing risk of crossing the thresholds that keep the Earth in a relatively stable domain. Until recently, our individual behaviors and collective institutions have been shaped primarily by change that we can envision relatively easily on a human time scale. Our behaviors are not tuned to the slow and imperceptible—but systematic—changes that can drive dramatic shifts in Earth's systems.

Planetary shifts can be rapid: the glaciation of the Younger Dryas, an abrupt climatic change resulting in severe cold and drought, occurred roughly 11,500 years ago, apparently over only a few decades. Or such shifts can unfold slowly: the Himalayas took over a million years to form. Shifts can emerge as the result of extreme events such as volcanic eruptions, or of relatively slow processes, such as the movement of tectonic plates. Though we still don't completely understand the subtle relationship between local and global stability in complex systems, several scientists hypothesize that the increasing complexity and interdependence of socioeconomic networks can produce "tipping cascades" and "domino dynamics" in the Earth's system, leading to unexpected regime shifts (Helbing 2013; Hughes et al. 2013).

Planetary Challenges and Opportunities

A planetary perspective on envisioning and building cities that we would like to live in—cities that are livable, resilient, and exciting—provides many challenges and opportunities. To begin, it requires that we expand the spectrum of imaginary archetypes. Current archetypes, from biological determinism to an equally narrow techno-scientific optimism, reflect skewed and often extreme simplifications of how the universe works (figure 10.1). At best, they are accurate but incomplete accounts of how the world works. How can we reconcile the messages contained in catastrophic-versus-optimistic views of the future of Earth? And how can we hold divergent explanations and arguments as plausibly true? Can we imagine a place where humans have co-evolved with natural systems? What does that world look like? How can we create that future in the face of limited knowledge and uncertainty, holding all these possible futures as plausible options?

The concept of planetary boundaries offers a framework for humanity to operate safely on a planetary scale. Rockström et al. (2009) developed the concept to inform us about the levels of anthropogenic change that can be sustained while avoiding potential planetary regime shifts that would dramatically affect human well-being. The concept does not imply, nor does it exclude, planetary-scale tipping points associated with human drivers. Hughes et al. (2013) addressed some misconceptions surrounding planetary-scale tipping points, especially the confusion of a system's rate of change with the presence or absence of a tipping point. To avoid the potential consequences of unpredictable planetary-scale regime shifts, we must shift our attention toward drivers and feedbacks rather than focusing exclusively on the detectable system responses. Rockström et al. (2009) also identified nine areas that are most in need of set planetary boundaries: climate change, biodiversity loss, input of nitrogen and phosphorus into soils and waters, stratospheric ozone depletion, ocean acidification, global consumption of freshwater, changes in land use, air pollution, and chemical pollution.

To provide a planetary perspective at the scale where policy development and decision-making occur, Steffen et al. (2015) further advanced the planetary boundary concept by introducing a two-tier approach to emphasizing cross-scale interactions and accounting for regional-level heterogeneity. They identified two key boundaries—climate change and biosphere integrity—as system-scale emergent properties of a tightly connected web of biophysical processes that have the potential to drive the Earth system into a new state. However, they did not account for either the regional distribution of the impact or historical patterns—important dimensions that, they acknowledged, are essential if the

FIGURE 10.1 Archetypes. Sources (*clockwise from top left*): Dutch Delta Works; East River Blueway Plan/WXY Studio; Aqualt-by-Studio-Lindfors; Andrew Burton, Getty Images.

framework is to serve as a guide for human development toward global sustainability.

A different emphasis is proposed by those scientists who have advanced the concept of planetary opportunities: solution-oriented research to provide realistic, context-specific pathways to a sustainable future (DeFries et al. 2012). The idea is that we must shift our attention to how human ingenuity and creativity can expand our ability to enhance human well-being (through, e.g., improved food security and human health) while minimizing and reversing environmental impacts. The concept is grounded in human innovation and our capacity to develop alternative technologies, implement green infrastructure, and reconfigure institutional frameworks. Opportunities to develop solution-oriented research approaches and explore innovative policy strategies are amplified on an urbanizing planet, where such solutions can be replicated and can transform the way we build cities and inhabit the Earth.

Imagining a Resilient Urban Planet

While the different images of the future in the emerging archetypes are both plausible and informative, they speak about the present more than the future. They are all extensions of the current trajectory, as if the future would unfold along a path defined by our current ways of asking questions and our current ways of understanding and solving problems. Yes, these perspectives do account for uncertainty, but it is defined by the confidence intervals around an extrapolated trajectory. And both stories are grounded in the inevitable dichotomies of humans versus nature and technology versus ecology. These views are, at best, an incomplete account of what is possible: they reflect a limited ability to imagine the future beyond such archetypes. Why can we imagine smart technologies but not smart behaviors, smart institutions, and smart societies? Why think only of technology and not of humans and their societies, which co-evolve with other life on Earth?

Understanding the co-evolution of human and natural systems is key to building a resilient society and transforming our habitat. Among the greatest questions in biology today is whether natural selection is the only process driving evolution and, if not, what the other potential forces might be. To understand how evolution constructs the mechanisms of life, molecular biologists would argue that we must first understand the self-organization of genes governing the evolution of cellular processes and influencing evolutionary change (Johnson and Kwan Lam 2010). In order to adequately understand the co-evolution of human and natural systems, we must embrace a complementary perspective on the forces driving evolution and the role that natural selection and self-organization play in constraining natural selection at different stages of the evolutionary process.

To function, life on Earth depends on the close cooperation of multiple elements. Biologists are curious about the properties of complex networks that supply resources, process waste, and regulate the system's functioning at various scales of biological organization. West and Brown (2005) proposed that natural selection solved this problem by evolving hierarchical, fractal-like branching. Other characteristics of evolvable systems include flexibility (e.g., phenotypic plasticity) and novelty. This capacity for innovation is an essential precondition for any system to function. Gunderson and Holling (2002) have noted that if systems lack the capacity for innovation and novelty, they may become overconnected and dynamically locked, unable to adapt. To be resilient and evolve, they must create new structures and undergo dynamic change. Differentiation, modularity, and cross-scale interactions of organizational structures have been described as key characteristics of systems that are capable of simultaneously adapting and innovating (Allen and Holling 2010).

To understand the co-evolution of human-natural systems also requires advances in the social theories that explain how complex societies and cooperation have evolved. What role does human ingenuity play? In this book, I have proposed that coupled human-natural systems are not governed only by either natural selection or human ingenuity but by hybrid processes and mechanisms. It is their hybrid nature that makes them unstable and, at the same time, able to innovate. This novelty of hybrid systems is key to reorganization and renewal. Urbanization modifies the spatial and temporal variability of resources, creates new disturbances, and generates novel competitive interactions among species. This is particularly important because the distribution of ecological functions within and across scales is key to a system's ability to regenerate and renew itself (Peterson, Allen, and Holling 1998).

Will the human species rise to the challenge and opportunity that nature has given us? Can we evolve in cooperation with other species toward a hybrid planet (Frank, Alberti, and Kleidon 2016)? Scientists around the world have alerted us to our role as a geological force that shapes the global landscape and evolution of Planet Earth (Crutzen and Stoermer 2000). We are driving the sixth mass extinction (Kolbert 2015) and changing our climate (IPCC 2014). Turning the tide will require a significant shift in the human enterprise that only the power of people can generate through their collective imagination and action. The climate deal signed by 195 nations on December 13, 2015 (UNFCCC 2015), might signal humanity's emerging awareness of our responsibility to the planet. Whether we are actually able to keep the global temperature within 2 degrees Celsius of preindustrial levels, as agreed in this deal, has yet to be seen. But if we are to be successful, it is cities that must lead in this ambitious transformation.

The City That Thinks Like a Planet: What Does It Look Like?

Although I have ventured to pose this question, I will not attempt to provide an answer. In fact, no single individual can. The answer resides in the collective imagination and evolving behaviors of peoples of diverse cultures who inhabit the vast array of regions across the planet. Humanity has the capacity to think in the long term. Indeed, throughout history, people in societies faced with the prospect of deforestation or other environmental changes have successfully engaged in long-term thinking. Consider, for example the Tokugawa shoguns, Inca emperors, New Guinea highlanders, and sixteenth-century German landowners (as discussed in Diamond 2005) or, more recently, the Chinese efforts at reforestation and bans on logging of native forests.

Many European countries, and the United States, have dramatically reduced their air pollution while increasing their use of energy and their combustion of fossil fuels. Humans have the intellectual and moral capacity to do even more when they tune in to challenging problems and engage in solving them.

A city that thinks like a planet is not built on previously set design solutions or planning strategies. Nor can we assume that the best solution would work equally well across the world, regardless of place and time. Instead, such a city must be built on principles that expand its drawing board and collaborative actions that include planetary processes and scales to integrate humanity into the evolution of Earth. Such a view acknowledges the history of the planet in every element or building block of the urban fabric, from the building to the sidewalk, from the backyard to the park, from the residential street to the highway. It is a view that is curious about understanding who we are and about taking advantage of novel patterns, processes, and feedbacks that emerge from human and natural interactions. It is a city grounded in the here and the now and simultaneously in the different temporal and spatial scales of human and natural processes that govern the Earth. A city that thinks like a planet is simultaneously resilient and able to change.

How can such a perspective guide decision-making in practice? Urban planners and other decision-makers strategizing about investments in public infrastructure want to know whether there are generic properties of city structure and governance that predict the capacity to adapt and transform. Can such shifts in perspective, toward a planetary view, provide a new lens and interpretation of the evolution of human settlements, adaptation to change, and success? Emerging evidence from the study of complex systems indicates that systems with greater heterogeneity (e.g., economic systems with diverse economic activities and ecosystems with a diversity of species) and greater modularity (where some components are independent) tend to have greater adaptive capacity than those characterized by highly connected, homogeneous elements (Scheffer et al. 2012).

Other properties of complex systems that enhance adaptive capacity and allow innovation are cross-scale interaction, early warning, and self-organization (figure 10.2). How do these qualities apply to cities?

Diversity allows systems to be flexible and cities to function under a wide range of conditions (e.g., with multiple modes of transportation). In October 2012, after Hurricane Sandy, the subway in New York City flooded unexpectedly and shut down for a week, potentially disrupting many interconnected activities. Yet it is under such circumstances that we encounter the greatest surprises: in New York, the flexibility created by an imperfect and redundant urban infrastructure provided alternatives and workarounds.

Modularity facilitates autonomous functionality and allows a system such as the urban built infrastructure to contain disturbances and avoid cascading effects. The modular electric grid is a prime example: interdependent networks are arranged such that a failure in one place leads to failures in other places. Connectivity may stabilize some processes, by reinforcing generator pathways, but it may also create unstable power systems that propagate failure across networks that are highly interdependent. Modular electric grids make it possible to isolate parts of the systems, which may then continue to operate independently and provide substitutive functionality during extreme events.

Cross-scale interactions allow for functional redundancy across scales and allow a system to respond to disturbance by exploiting innovative options for service substitutions (e.g., energy, food, and water sources and delivery). Like cross-scale resilience, which is produced by the species of a functional group that operate across scales, urban infrastructure sys-

Resilience Principle	Hypotheses	Example
Heterogeneity	Allows system flexibility and the ability to function under a wide range of conditions	Multimodal transportation 
Modularity	Allows autonomous functionality and the ability to contain disturbances and avoid cascading effects	Modular electric grid 
Cross-scale interactions	Allows functional redundancy across scales, added capacity under contingency, and creative solutions for service substitutions	Energy and water sources and delivery 
Early warning	Anticipating catastrophic events and allowing the system to fail safely also depends on creating early warning systems that allow for essential functions to be performed when part of the system fails	Realtime monitoring systems 
Self-organization	Resilient systems are also self-organizing, a quality that enables natural and social systems to change their internal structure and their function in response to external circumstances	Sand ripples and stock markets 

FIGURE 10.2 Resilience principles: emerging hypotheses regarding properties of resilient complex systems. Photographs: bike on bus: SounderBruce; electric grid: Chad Cooper; water delivery: Layne Construction pipeline (Pueblo, Colorado); warning signals: U.S. Army; sand dune: ccdoh1.

tems that operate multiple services reinforce system functionality and thus enhance resilience.

Early warning is an essential component of adaptation and transformation. Anticipating catastrophic events by establishing early warning systems, together with a modular architecture, allows a system to fail safely by permitting essential functions to be performed while part of the system fails. Early warning mechanisms (e.g., indicators, real-time warnings, and crash zones) provide real-time feedback and help us to anticipate catastrophic events.

Self-organization is a process in which patterns at the global level of a system emerge from numerous interactions among the lower-level components of the system itself. It enables natural and social systems to change their internal structures and their functions in response to external circumstances (e.g., sand ripples or stock market shifts). Novel forms of social organizations and socioecological functions can emerge from interactions at lower scales among multiple agents.

Translating These Concepts into Practice

A co-evolutionary perspective shifts the focus of planning toward human-natural interactions, adaptive feedback mechanisms, and flexible institutional settings. Instead of predefining "solutions" that communities must implement, such a perspective focuses on understanding the rules of the game in order to facilitate self-organization and carefully balanced top-down and bottom-up management strategies. Planning relies on principles that expand the heterogeneity of forms and functions in the structures and infrastructures that support a city, and plans support selective modularity (as opposed to generalized connectivity) to create interdependent decentralized systems with adequate autonomy to evolve.

Local governments must make important decisions about land-use management and investments in infrastructure that can influence the direction of urban development in the near future. Future policies and management practices will succeed or fail based on their ability to take into account the complexities and uncertainties of these systems. To address the inherent uncertainty of coupled human-natural systems, we must challenge the myths of stability and optimality that have long characterized urban planning. The search for optimal solutions is based on three assumptions: that thresholds remain constant over time, that they can be detected and predicted, and that what is resilient in one region and at one scale is resilient across regions and across scales. Yet increasing evidence challenges the universality of these assumptions.

Resilience depends on biophysical and socioeconomic conditions that vary across regions and scales. The most recent IPCC report (IPCC 2014) illustrates significant differences in both the potential risks that urban communities across different regions will face and their adaptive capacities. According to the IPCC Working Group II, which focuses on urban areas, four factors explain differences across cities: local government capacity, the proportion of residents served with risk-reducing infrastructure and services, the proportion living in housing built to appropriate health and safety standards, and the levels of risk from climate change's direct and indirect impacts (Revi et al. 2014). The report does caution that the current evidence is still too limited to draw conclusions that explain adaptive capacity and resilience across communities, but it is increasingly clear that cities will require different, location-specific strategies in order to adapt to environmental change and build resilience (ibid.).

I suggest five principles for planning under uncertainty that can enable resilience and innovation in urban ecosystems:

1. Maintain the diversity of urban patterns and processes and a variety of infrastructure typologies to support diverse human and ecosystem functions rather than aim for an optimal city design.
2. Focus on maintaining self-organization and increasing adaptation capacity rather than aiming to reduce variability, control change, and eliminate uncertainty.
3. Challenge assumptions of current policies and strategies and actively reconfigure problem definitions and policy actions.
4. Create options for learning through experiments and design flexible strategies that allow us to adapt them and implement what we learn.
5. Expand the time scale of decision-making by designing policies and strategies to be robust under divergent but plausible futures.

In cities across the world, people are setting examples that will allow these principles to be tested. Human perceptions of time and experiences of change are emerging as keys to achieving the shift to a new perspective for building cities. We must develop reverse experiments to explore what works—what shifts the time scales of individual and collective behaviors. We must direct our attention toward the opportunities that urban transformations may provide for an urban planet. Which lessons for urban ecology can we draw from the evolution of urban systems and their persistence through time?

Translating principles of resilience and innovation to the practice of urban design and planning requires a shift from our current fragmented search for solutions toward an integrated and dynamic view of urban systems. The form and infrastructure of resilient hybrid cities are heterogeneous and modular. Hybrid cities rely on innovative technology and self-organized governance. Transportation, energy, water, and waste management systems are interconnected and link housing, employment, and business clusters across multiple scales. Local governments of these cities invest in innovative infrastructure and technologies (e.g., bus rapid transit, or BRT) and in new forms of finance (e.g., Qualified Energy Conservation Bonds, or QECBs) and governance (e.g., horizontal governance).

Emerging evidence suggests that the most innovative cities are typically more productive, more socially inclusive, and more resilient and that they have lower carbon emissions (Floater et al. 2014). Many cities across the world are implementing innovative solutions to foster new urban development models and accelerate transformation. New technologies and the digital revolution have provided unanticipated opportunities for increasing efficiency by sharing resources, managing service demands, monitoring, and providing urban dwellers the real-time, people-centered information required to make informed decisions (World Economic Forum 2015). Smart transportation systems—including, for example, BRT, bicycle "superhighways," car and bicycle sharing, smarter traffic information systems, and electric vehicles—have appeared in the past decade in cities across Europe, the Americas, China, and India (figure 10.3).

Several Northern European cities have adopted successful strategies to cut greenhouse gases, combining these strategies with innovative approaches that allow the cities to adapt to the inevitable consequences of climate change. One example is the Copenhagen 2025 Climate Plan, which lays out a path for Copenhagen to become the world's first carbon-neutral city by 2025 through efficient zero-carbon mobility and building. The city is building a subway project that will place 85 percent of its inhabitants within 650 yards of a metro station. Nearly three-quarters of Copenhagen's emissions reductions will be realized as people transition to less carbon-intensive ways to produce heat and electricity via a diverse supply of clean energy: biomass, wind, geothermal, and solar. Copenhagen is also one of the first cities to adopt a climate adaptation plan that will reduce its vulnerability to the extreme storm events and rising seas expected over the next hundred years.

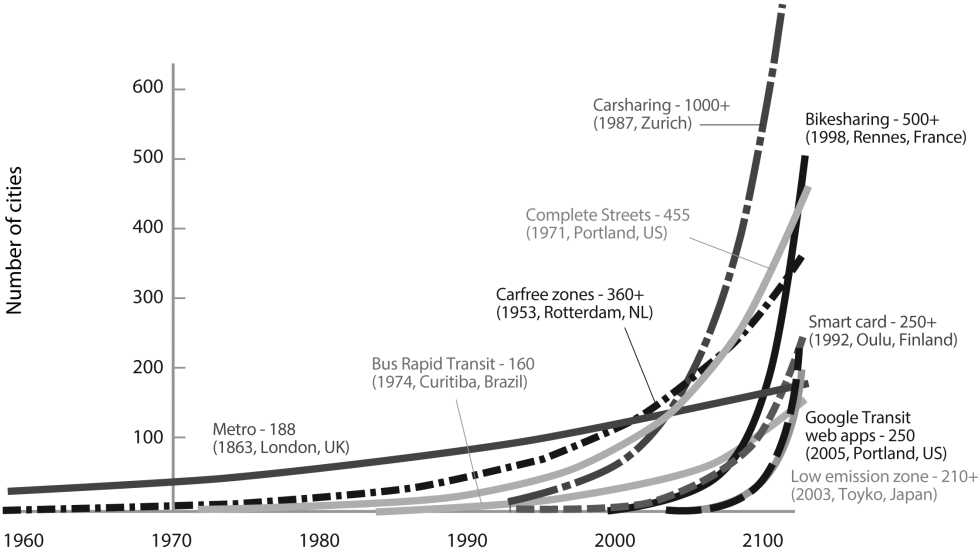

FIGURE 10.3 Smart transportation systems in selected cities. Source: Embarq 2013.

In the Netherlands, alternative strategies are being explored to allow people to live with the inevitable floods. These strategies include building floating communities on water and engineering and implementing adaptive beach protections that take advantage of natural processes. The Sand Engine, completed in 2011, is an experimental project developed by Building with Nature (a consortium of Dutch industries, universities, research institutes, and public water agencies) that uses a combination of wind, waves, tides, and sand to replenish the eroded coasts. The Dutch Rijkswaterstaat, the executive agency of the Dutch Ministry of Infrastructure and the Environment, and the South Holland provincial authority deposited enormous quantities of sand as a one-by-two-kilometer artificial peninsula extending into the sea; waves and currents will redistribute it over time, building dunes and beaches to protect the coastline.

New York is setting an example for long-term planning by combining adaptation and transformation strategies into its plan to build a resilient city: in the summer of 2013, in the wake of Hurricane Sandy, then-mayor Michael Bloomberg outlined a US$19.5 billion plan to defend the city against rising seas. In many rapidly growing cities across the world, similar leadership is emerging. For example, in 2009, Johannesburg adopted one of the first climate change adaptation plans, as have Durban and Cape Town in South Africa and Quito in Ecuador, along with Ho Chi Minh City in Vietnam, which has established a partnership with Rotterdam in the Netherlands to develop a resilience strategy.

These new approaches to smart design and technologies are supported by novel financial mechanisms. Cities are using municipal bonds to finance innovative infrastructure projects that can attract large investors. In 2013, Johannesburg issued a US$136 million green bond to finance investments in a diverse set of solutions, from hybrid buses to biogas energy and rooftop solar water heaters. In the United States, models such as QECBs allow local governments to borrow money to fund energy conservation projects. Municipal bonds and infrastructure trusts have significant potential to accelerate transformation.

Novel institutional frameworks and policy approaches that embrace uncertainty and build resilience are being tried experimentally in a few metropolitan areas. Wise et al. (2014) examined how institutional settings and governance may facilitate or constrain adaptation. Rather than focusing on adaptation as an isolated set of interventions, they conceptualized adaptation as a continual pathway of change and response informed by past actions and shaping the range of future options. This approach, called *adaptation pathways*, emphasizes five critical elements: multidimensionality, interdependence, intertemporality, monitoring, and social processes.

Multidimensionality acknowledges that climate adaptation cannot be separated from the cultural, political, economic, environmental, and developmental contexts in which it occurs; it must be thought of as part of a range of societal responses to change. *Interdependence* recognizes interactions across spatial scales, sectors, and jurisdictional boundaries, which can lead to threshold effects and require coordination. *Intertemporality* implies that future pathways are contingent on historical pathways; it acknowledges the potential for lock-in and warns us to be wary. *Monitoring* means the implementation of early warning systems and detection of warning signals to assess dynamic changes and the effectiveness of interventions and to respond adaptively. *Social processes* enable or constrain the rules, values, and knowledge that govern adaptation and resilience and that must be embedded in planning strategies

Box 10.1. Pathways to Resilience: The New York City Example

In 2008, Mayor Michael Bloomberg convened the First New York City Panel on Climate Change (NPCC 2010) to assist the city in assessing risk and developing an adaptation strategy. A major innovative element introduced by the panel was the concept of "flexible adaptation pathways" as an approach to responding to climate change (Yohe and Leichenko 2010). New York's flexible adaptation approach combines two major concepts: *resilience* and *dynamic robustness* (W. E. Walker, Haasnoot, and Kwakkel 2013). This approach is based on a study done by the City of London and the UK Environment Agency to renovate the Thames barriers (Lowe et al. 2008; Ranger, Reeder, and Lowe 2013).

The level of risk that is acceptable to society fluctuates as a result of changes (e.g., an experience of a major hurricane). Without climate change mitigation or adaptation, inflexible adaptation standards may improve conditions on a relatively short time line but eventually will result in crossing the acceptable risk level. Flexible adaptation consists

to ensure that adaptive pathways succeed. Rosenzweig and Solecki (2014) provided a practical example of this approach and showed how it might be applied in their assessment of the flexible adaptation pathways being developed to manage climate risk in response to Hurricane Sandy (box 10.1).

To think like a planet and explore what is possible, we may need to reframe our questions. Instead of asking what is good for the planet, we must ask what is good for a planet inhabited by people, or what a good human habitat on Earth might be. And instead of seeking optimal solutions, we should identify principles that will inform diverse communities across the world. The best choices may be temporary, since we do not fully understand the mechanisms of life and we cannot predict the consequences of human actions. They may very well vary with place and depend on their own histories, but human actions may also constrain the choices available for life on Earth.

of a successive set of strategies developed and implemented as knowledge and understanding of climate change proceed. These pathways are reevaluated and readjusted over time as new knowledge and information become available.

The city is developing short-term actions that reduce risk iteratively while laying a framework to guide long-term flexibility and resilience. Proposed adaptation policies for the city include reducing flood risks to infrastructure, buildings, and highly exposed communities through small- to medium-scale flood protection strategies (e.g., levees), regulatory approaches (e.g., building codes), and improving responses to extreme events (New York City 2011). Mitigation actions may be necessary for the adaptation to succeed. New York's flexible adaptation framework encompasses both mitigation and adaptation and enables planners to consider long-range goals and ways to translate them into short-term objectives. Based on an initial report by the NPCC, the city updated PlaNYC, its long-term sustainability plan, by explicitly acknowledging that risk management strategies must evolve through time in response to continuous climate risk assessment, evaluation of adaptation strategies, and monitoring. ●

Scenario Planning

Scenario planning offers a systematic and creative approach to thinking about the future. It challenges scientists and practitioners to expand their mindsets (see chapter 9). It provides a tool that we can use to deal with the limited predictability of changes on the planetary scale and to support decision-making under uncertainty. Scenarios help bring the future into present decision-making processes (Schwartz 2005), broaden perspectives, prompt new questions, and expose possibilities for surprise. They have several other valuable features: they can shift attention toward resilience, redefine decision frameworks, expand the boundaries of predictive models, highlight the risks and opportunities of alternative future conditions, monitor early warning signals, and identify robust strategies (Alberti, Russo, and Tenneson 2013).

A fundamental objective of scenario planning is to explore interactions among uncertain trajectories that would otherwise be overlooked.

Scenarios highlight the risks and opportunities of plausible future conditions. The hypothesis is that if planners and decision-makers look at multiple divergent scenarios, they will engage in a more creative process for imagining solutions that would be otherwise invisible. As I noted earlier, scenarios are narratives of plausible futures; they are not predictions. But they are extremely powerful when combined with predictive modeling. They help expand boundary conditions and provide a systematic approach that we can use to deal with intractable uncertainties and to assess alternative strategic actions, and they can help us modify model assumptions and assess the sensitivities of model outcomes. Building scenarios can help us highlight gaps in our knowledge and identify the data required to assess future trajectories.

Scenarios can also highlight important warning signals, allowing decision-makers to anticipate unexpected regime shifts and respond in timely and effective ways. They can support decision-making in uncertain conditions by providing a systematic way to assess the robustness of alternative strategies under a set of plausible future conditions. Although we do not know the probable impacts of uncertain futures, scenarios provide the basis for assessing critical sensitivities and help us to identify both potential thresholds and irreversible impacts, allowing us to maximize the well-being of both humans and our environment.

A New Ethic for a Hybrid Planet

More than half a century ago, Aldo Leopold (1949) introduced the concept of "thinking like a mountain": he wanted to expand the spatial and temporal scale of land conservation by incorporating the dynamics of the mountain. Defining a land ethic, as Leopold did, was a first step in acknowledging that we are all part of a larger community that includes soils, waters, plants, and animals and all the components and processes that govern the land, including the prey and predators. Along the same lines, Paul Hirsch and Bryan Norton (2012) have articulated a new environmental ethic by suggesting that we "think like a planet." Building on their idea, I propose that we must expand the dimensional space of our mental models of urban design and planning to the planetary scale.