CHAPTER 2

How Scale Matters: Some Concepts and Findings

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This chapter summarizes a number of concepts related to how geographic scale matters in conducting large, integrative nature-society assessments, such as the Millennium Ecosystem Assessment (MA) and the reports of the Intergovernmental Panel on Climate Change (IPCC). Such concepts relate both to (a) how phenomena and processes differ between scales and (b) how phenomena and processes at different scales affect each other. The chapter also considers lessons learned about how geographic scale relates to knowledge bases. Although it notes that temporal and institutional scale are important, in line with the conceptual framework of the subglobal component of the MA it focuses on geographic scale.

These questions for nature-society assessments are, of course, related to one of the great overarching intellectual challenges across a wide range of sciences: understanding relationships between macroscale and microscale phenomena and processes (Wilbanks and Kates 1999). Examples include biologists and ecologists considering linkages between molecules and cells, on the one hand, and biomes and ecosystems, on the other, related to such issues as biocomplexity; economists considering relationships between individual consumers and firms, on the one hand, and national and global economies, on the other, related to such issues as efficiency and equity; and such other scientific fields as far afield as fluidics, which considers how the behavior of fluids changes with scale and how these differences interact. In the spirit of traditions such as general systems theory, it is not uncommon to explore applications of findings in one field about how scale matters as possible hypotheses for another (for an early example of explorations of how scale shapes interactions between form and function, see Thompson 1942).

Basic Concepts

Some basic concepts about how we consider geographic scale as an aspect of nature-society assessments are summarized in Wilbanks 2003, Millennium Ecosystem Assessment 2003, and Zermoglio et al. 2005. Millennium Ecosystem Assessment 2003 defines scale as the physical dimension of a phenomenon or process in space or time, expressed in physical units. According to this perspective, "a level of organization is not a scale, but it can have a scale" (MA 2003, 108; also see O'Neill and King 1998).

Arrayed along a geographic scale continuum from very small to very large, most processes of interest establish a number of dominant frequencies; they show a kind of lumpiness, organizing themselves more characteristically at some scales than others (see, for instance, Holling 1992). Recognizing this lumpiness, we can concentrate on the scales that are related to particular levels of system activity—for example, family, neighborhood, city, region, and country—and at any particular level subdivide space into a mosaic of "regions" to simplify the search for understanding. In many cases, smaller-scale mosaics are nested within larger-scale mosaics; therefore, we can often think in terms of spatial hierarchies.

Although some care is needed in extrapolating from one field of study to another, in some cases (e.g., in ecology) relationships exist between spatial and temporal scales. For instance, it appears that in many cases shorter-term phenomena are more dominant at local scales than at global scales, while long-term phenomena are the converse. On the other hand, in human systems infrastructure, decisions involving lifetimes of thirty years or more may be made at very local scales, while political perspectives at a national scale are often focused on very-near-term costs and benefits.

What we are discovering is that place is more than an intellectual and social construct; it is also a context for communication, exchange, and decision making. Place has meaning for local empowerment, directly related to equity. In fact, a sense of place is related to personal happiness in the face of global space-time compression (see, for example, Harvey 1989).

Based partly on such concepts, it has been suggested that geographic scale matters in seeking an integrated understanding of global change processes and that understanding linkages between scales is an important part of the search for knowledge (Wilbanks and Kates 1999; also see Kates and Wilbanks 2003 and Association of American Geographers 2003). Several of the reasons have to do with *how the world works.* The forces that drive environmental systems arise from different domains of nature and society—for example, Clark has shown that distinctive systems embedded in global change processes operate at different geographic and temporal scales (Clark 1985). Within this universe of different domains, local and regional domains relate to global ones in two general ways: systemic and cumulative (Turner et al. 1990). Systemic changes involve fundamental changes in the functioning of a global system, such as effects of emissions of ozone-depleting gases on the stratosphere, which may be triggered by local actions (and certainly may affect them) but that transcend simple additive relationships at a global scale. Cumulative changes result from an accumulation of localized changes, such as groundwater depletion or species extinction; the resulting systemic changes are not global, although their effects may have global significance.

A second reason that scale can matter is that the scale of *agency*—the direct causation of actions—is often intrinsically localized, while at the same time such agency takes place in the context of *structure*: a set of institutions and other regularized, often formal relationships whose scale is regional, national, or global. Land use decisions are a familiar example.

A third reason that scale can matter is that the driving forces behind environmental change involve interactions of processes at different locations and areal extents and different time scales, with varying effects related to geographic and temporal proximity and structure. Looking only at a local scale can miss some of these interactions, as can looking only at a global scale.

Several additional reasons why scale matters have to do with *how we learn about the world.* One of the strongest is the argument that complex relations among environmental, economic, and social processes that underlie environmental systems are too complex to unravel at any scale beyond the relatively local (National Academy of Sciences/National Research Council 1999). A second reason is that a portfolio of observations at a detailed scale is almost certain to contain more variance than observations at a very general scale; the greater variety of observed processes and relationships at a more local scale can provide for greater learning about the substantive questions being asked. In other words, variance often contains information rather than "noise." A third reason is that research experience in a variety of fields tells us that researchers looking at a particular issue from the top down can reach conclusions that differ dramatically from those of researchers looking at that very same issue from the bottom up. The scale embodied in the perspective can frame the investigation and shape the results, which suggests that full learning requires attention at a variety of scales.

These reasons, of course, do not mean that global-local linkages are salient for every question being asked about nature-society systems. What they suggest is more modest: that examinations of such changes should normally take time to consider linkages among different scales, geographic and temporal, and whether those linkages might be important to the questions at hand (Wilbanks, forthcoming).

In any case, they also suggest that integrated assessments of nature-society relationships should be sensitive to multiple scales rather than focused on a single scale (Wilbanks 2003; AAG 2003). One reason is that selection of a single scale can frame an investigation too narrowly because questions and research approaches characteristic of that scale tend to dominate and because upscaling or downscaling information from other scales requires compromises that often lose information or introduce biases. Another reason is that phenomena, processes, structures, technologies, and stresses operate differently at different scales and thus the implications for action can depend on the scale of observation. Figure 2.1 is an example from recent research.

Yet another reason is that a particular scale may be more or less important at different points in a single cause-consequence continuum and therefore less appropriate for exploring some of the points. Figure 2.2 is an example.

Finally, institutions important for decision making about the processes being examined operate at different scales. For these reasons, no single scale is ideal for broad-based investigation, although comparative studies at a single scale can contribute important insights (e.g., Schellnhuber and Wenzel 1998; Schellnhuber, Lüdeke, and Petschel-Held 2003; AAG 2003).

Findings about Scale Differences

A number of recent nature-society assessments, in addition to the Millennium Ecosystem Assessment, have helped to illuminate issues related to how scale matters in such assessments (AAG 2003; National Assessment of Climate

Figure 2.1
Scale matters in comparing net benefits from mitigation and adaptation responses to concerns about climate change impacts. For instance, at a global scale, mitigation ("avoidance") tends to appear preferable because many potentially dangerous impacts could be beyond capacities to adapt, whereas at a regional scale in an industrialized country, adaptation can appear preferable because many of the benefits of mitigation actions are external to the region. *(From Wilbanks et al., forthcoming.)*

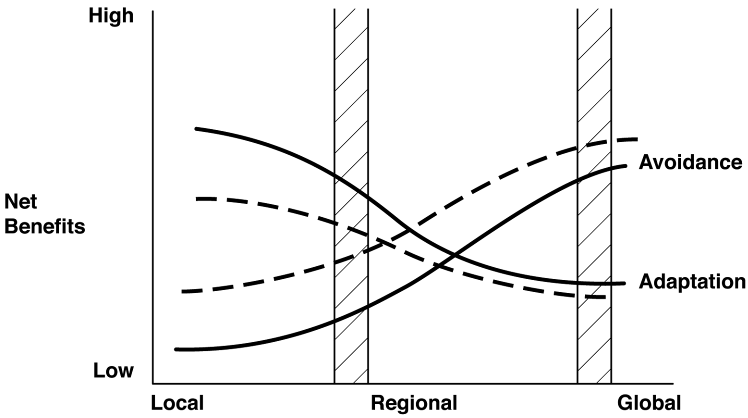


Figure 2.2
Climate change and its consequences include a number of different processes, which often differ in the scale domains where consequences are focused. *(From Kates and Wilbanks, 2003.)*

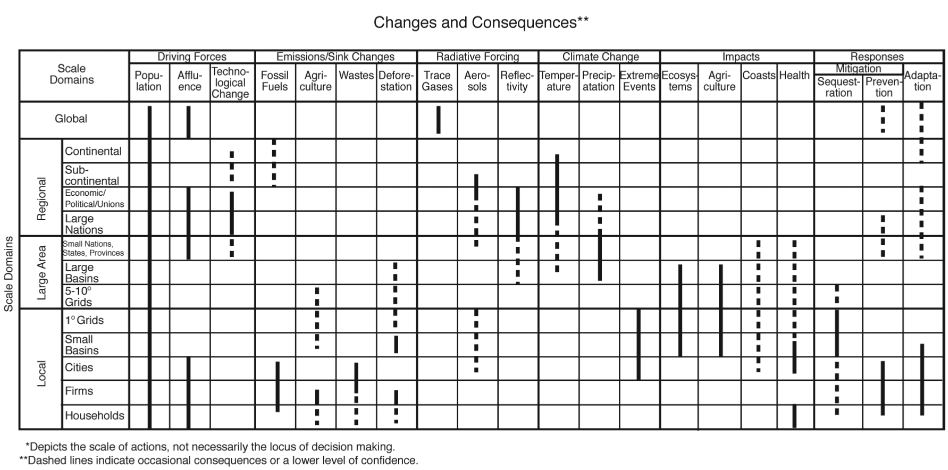
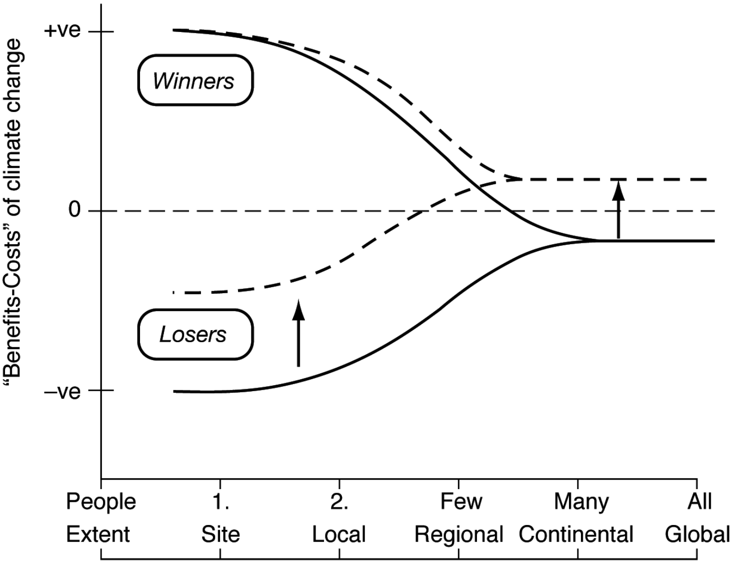


Figure 2.3

The first assessment of consequences of climate change in Canada found that the variance in net effects was considerably greater at local scales than at larger scales, as illustrated here. The solid lines depict net benefits without adaptive response; dotted lines indicate net effects of adaptation. *(From Environment Canada 1997.)*

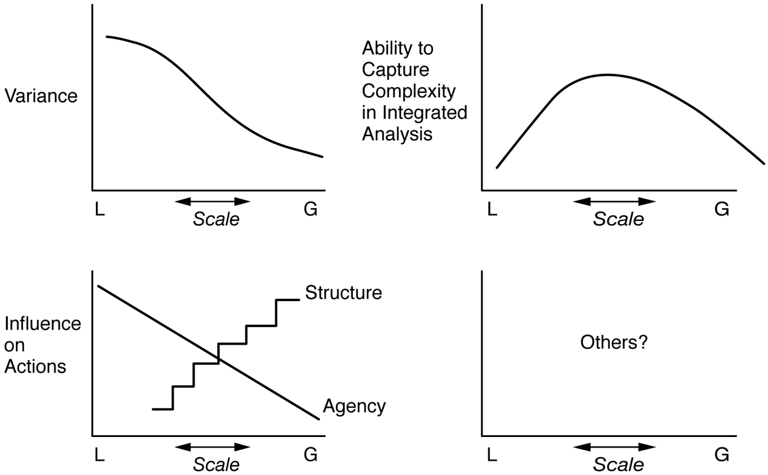


Change 2000; NAS/NRC, 1999). More recent findings have emerged from regional and local studies by the Assessments of Impacts and Adaptations to Climate Change (AIACC) project (http://www.aiaccproject.org) and the subglobal component of the Millennium Ecosystem Assessment (MA 2005). Also see listings of integrated studies of nature-society systems (http://sustsci.harvard.edu/integstudies.htm), local analyses of climate change adaptation experiences and potentials (http://www.sei.se/oxford/), and studies of environmental change vulnerabilities at various scales (http://www.vulnerabilitynet.org).

These investigations indicate that, as expected, observations of many variables at a more localized scale show greater variance and volatility. In other words, larger scales lose valuable information. Figure 2.3, from the Canadian national climate change impact assessment (Environment Canada 1997), was one of the earliest empirical findings of this nature in nature-society studies, supporting the theoretical expectations mentioned above.

Figure 2.4

Illustrations of several possible hypotheses about how scale matters. "L" indicates "Local"; "G" indicates "Global." There is room for considerable insight and innovativeness in suggesting other such hypotheses.



The literature also finds that analyses and assessments at different scales tend to be associated with different research paradigms and styles. As one example, in analyses of climate change responses, work at a global or national scale tends to be characterized by quantitative analysis, using net present value metrics, while work at a small-regional or local scale tends to involve integrated assessments, including significant stakeholder involvement (Wilbanks et al., forthcoming).

Downscaling and upscaling, in fact, are likely to contribute different insights; for instance, bottom-up investigations often provide different understandings compared with top-down investigations. As one illustration, the Global Change in Local Places (GCLP) project, by the American Association of Geographers, found that top-down assessments of potentials of technologies to reduce greenhouse gas emissions in local places tended to overestimate those potentials because they were not sensitive to local obstacles and constraints, whereas bottom-up assessments tended to underestimate the potentials because they were not fully informed about directions of technological and policy changes (Kates and Wilbanks 2003; AAG 2003).

Other findings include (a) that different scales are related to different institutional roles, and that the scale of decisions is often poorly matched with the scale of the processes being decided upon, and (b) that the choice of a scale and a set of boundaries is not politically neutral, even if the choice is not based on political considerations (MA 2003).

Even though proposing a theoretical structure at this stage in our knowledge development would seem premature, it is possible to imagine moving in that direction by considering and testing a number of hypotheses that seem reasonable based on what we know so far. Figure 2.4 illustrates just a few of the relationships that might be explored.

Findings about Scale Relationships

Similarly, recent assessments have suggested findings about how phenomena and processes at different scales are linked with each other, although the knowledge base about cross-scale relationships is not as well developed as it is about scale differences. Most significantly, perhaps, GCLP indicates that in many cases cross-scale *interactions* are more significant than aggregate *differences* between scales (e.g., Kates and Wilbanks 2003; AAG 2003). For instance, local actions shape cumulative environmental conditions and democratic policy making at larger scales, while local actions are affected in turn by market signals, institutional structures, and technology portfolios arising at larger scales (figure 2.5). It is in the intertwining of local activity with larger structures that most nature-society phenomena and processes play out.

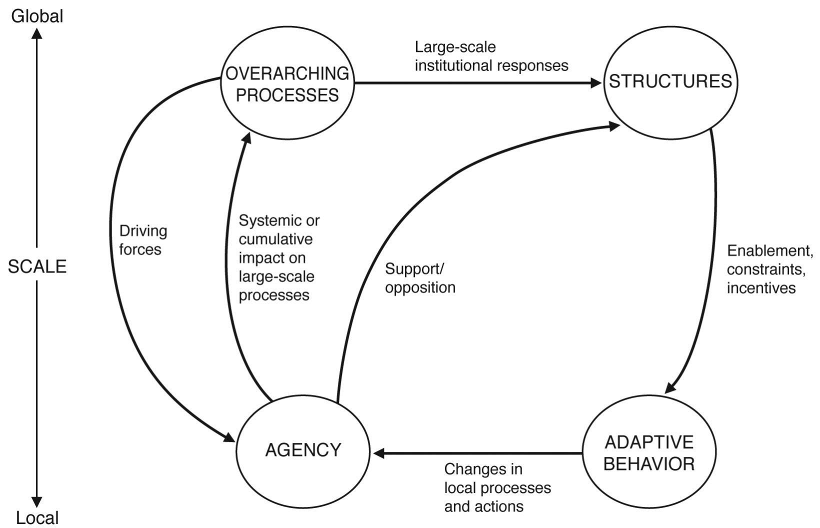
Cross-scale interactions can be considered in terms of certain basic dimensions they demonstrate:

- *Strength: powerful or weak.* Consider, for example, top-down regulatory controls versus bottom-up messages through representative democracies.
- *Constancy: constant or intermittent; periodic or irregular.* Consider, for instance, gradual climate change versus technology breakthroughs.
- *Directionality: mainly in one direction or the other, or mutual.* Most often, directionality distinguishes top-down interactions, such as through corporate management frameworks, from feedbacks in both directions through democratic government processes supported by an active free press.
- *Resolution: focused or broadcast.* An example is specific location problem solving versus general information provision.

Figure 2.5

Macroscale and microscale processes and phenomena interact across scales in ways such as shown here. For instance, local actions shaped by larger driving forces add up to impacts on large-scale processes. Institutional responses at larger scales, shaped by democratic support or opposition from smaller scales, lead to large-scale structures that provide enablement (or constraints) for local-scale adaptive behavior.

(From Association of American Geographers 2003.)



- *Context: additive or contradictory, in connection with other processes operating.* For instance, government policies that reinforce market signals have a different effect than do policies that differ from market signals.
- *Effect: stabilizing or destabilizing; controlling or enabling.* Among the many examples, terrorism arising from relatively local grievances can destabilize larger-scale units, while actions that provide conflict resolution can be stabilizing.
- *Intent: explicit and/or implicit.* Determining the intent of actions, for instance by large and small government, is not always easy, but intent is a fundamental aspect of cross-scale interactions, their effects, and their sustainability.

It is clear that cross-scale interactions are often associated with distinctive bridging-type institutional roles (Cash 2001); but in many cases involving human systems, relationships are too complicated to be incorporated into the kinds of hierarchy theory characteristic of ecological research (personal relationships, information flow, emission dispersal, etc.), and in many cases important kinds of data about the interactions are elusive (e.g., relationships between local phenomena and national or international corporate decision making).

In some cases, increasing understanding—at least at the current state of knowledge—seems to call for laying out rich narrative "story lines" and then exploring the connections from multiple base points (e.g., Root and Schneider's call [1995] for "strategic cyclical scaling"). Figure 2.5 illustrates such a story line. (For another example, see Kok et al. 2004.)

Findings about Scale Aspects of Knowledge Bases

Several of these findings speak directly to scale-related aspects of knowledge bases, especially the value of knowledge bases at a local scale and complexities in relating these knowledge bases to extra-local structures.

One set of findings addresses the potential value of local-scale studies and what that value may depend on. One finding shows that it is only in relatively focused place-based research that complex relationships among environmental, economic, and social processes can be traced, especially when the researchers are armed with specific local knowledge (NAS/NRC 1999). Of particular value is local knowledge about phenomena and processes not captured by data available to larger-scale analysts and modelers. For instance, data might not exist to document a relationship between temperature differences and health indicators in a local area, but a focus group discussion among local health care providers might provide a rich base of knowledge on the subject (e.g., Oak Ridge National Laboratory and Cochin University of Science and Technology 2003).

Another finding is that involving information and education infrastructures with a demonstrated commitment to the local area is the best way to facilitate cross-scale dialogues (Cash and Moser 2000). For example, communications channeled from global experts to local experts and then communicated by the local experts in interactions with local decision makers work far better than communications channeled between global experts and global decision makers and then between global decision makers and local decision makers (Cash and Moser 2000). Local experts are uniquely suited to help relate general and local knowledge because they are repositories themselves of both kinds of knowledge and because their life experiences include extensive contact networks in both worlds (AAG 2003).

Yet another value is the greater variance in information and experience that exists among a sample of local areas compared with a sample of larger areas; this increased variance offers greater opportunities for detailed understandings of complex causes and consequences (AAG 2003). In fact, observations of local circumstances—and especially adaptive behavior—can challenge generalizations about the regions in which they are located—for instance, the subglobal assessment component of the MA found that, in some cases, localities within regions considered highly stressed were relatively stable while some localities within regions considered relatively stable were relatively stressed (Pereira, Reyers, and Watanabe 2005; also see Kok 2001, 115).

Moreover, a local scale can be especially valuable in identifying sometimes overlooked or understudied issues related to environmental change (AAG 2003). By involving more information exchange between subject-matter analysts and the wider citizenry, a local scale contributes to a social process of learning and response. It can also help clarify differences in the local consequences of national and large-regional actions.

On the other hand, isolated local case studies are often problematic as bases for broader generalizations, especially when they are selected in part because of interesting kinds of unique characteristics. Their value for larger-scale understandings is enhanced when they are carefully chosen for comparability, use a common study protocol, and are compared with control studies, but this kind of interarea coordination is often difficult to arrange and implement. Local studies, based on local knowledge bases and perspectives, may also be limited by a lack of local understanding of larger-scale driving forces and trends, such as technological change (AAG 2003).

A second set of findings concerns challenges in relating the local and the global. In studies of climate change issues, at least, it is clear that some of the driving forces operate at a global scale while many of the phenomena that underlie environmental processes operate at a local scale (AAG 2003). Understanding climate change processes and responses requires attention to multiple scales and how they relate to one another. Studies of climate change issues at the two scales, however, are often poorly linked. Those moving from global toward local scales typically use climate change scenarios derived from global models as starting points, despite the absence of regional or local specificity in such models. Studies moving from the local toward the global are typically less quantitative, more participative, and related to different research traditions and disciplinary paradigms (Wilbanks et al., forthcoming). Connecting the two has generally been a challenge for what has been termed "analytic-deliberative" approaches (NAS/NRC 1996), where structured group processes—informed by a variety of analyses and bodies of experience—confront not only issues regarding different research approaches but also the fact that researchers examining an issue from a local perspective may reach conclusions different from those reached by analysts who view the very same issue from a global vantage point (and where it is possible that neither is wrong).

As indicated above, what we know from both research literature and practice is that local actions occur within the context of externally determined structures, from government and corporate policies to demography and technological change. For instance, a study of potentials to reduce greenhouse gas emissions in several local areas of the United States through local action concluded that local actions could yield substantial results under four sets of conditions: growing evidence of climate change impacts, related to largely external climate change forecasts and impact assessments; policy interventions that directly or indirectly associate emission reductions with local benefits, also largely externally derived; market or governmental incentives and assistance for local innovation; and technological change and improvement to enlarge the options available for local choice and application (AAG 2003). Unfortunately, few of these conditions exist at present.

A third set of lessons asks at what scale local studies should be performed. As reported above, lessons from assessments so far indicate that there is no one scale for every purpose. Because scale is related to function, and because different functions have different scales, a starting point in determining the appropriate scale is to clarify the functions of particular interest. In many cases, scales between assessments and the activities they consider are seriously mismatched (AAG 2003). Moreover, the scale selected affects the results by establishing boundaries between what is in and what is not, which can have social and political implications even if the selection is not politically motivated (MA 2003). In many cases, if the analysis is intended to inform decisions by particular institutions, it is worth considering whether to relate the scale to units for which or in which decisions are made.

Concluding Observations

Whereas a decade ago there might have been some debate about whether scale matters in far-reaching, integrative nature-society analyses and assessments, this issue seems to have been settled, with the debate shifting from the *importance* of multiscale assessments to (at least in the case of the U.S. Climate Change Research Program) the *practicality* of science-based assessments at the regional and local scales at the current state of data, tools, and knowledge (especially the forecasting of changes and impacts at a fine-grained scale).
The challenges are as follows:

- to show that regional and local assessments can be at least as sound scientifically as global assessments, where such initiatives as AIACC are very encouraging
- to show that qualitative deliberations and stakeholder participation, which are usually more important at a local scale, can contribute to the science of nature-society assessments as well as to their political acceptability
- to develop more effective approaches for facilitating open two-way interaction between experts, institutions, and interests across scales (for instance, developing guidelines for local assessments that are widely acceptable and useful, and replacing or supplementing quantitative large-scale scenarios with rich, informative narratives of different pathways for conceivable change).

In the longer run, of course, we will need to develop conceptual and methodological frameworks that incorporate both scale *differences* and scale *relationships.* But this development itself will need to include both top-down and bottom-up interactions, keeping its approaches consistent with its understandings of its subject.

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