Chapter 8

Process and Pattern

The last two chapters have shown that we need to think carefully about process. Network representations of relations among entities render the dynamics of interacting processes as static topological structures. These are convenient to analyze but discard process information. On the other hand, when we explicitly consider change through time, but ignore the driving processes, we may be unable to account for change effectively. In this chapter we address these omissions by considering process thinking in relation to geography, and how it might enhance computational representations of geographical phenomena.

We first explore *process philosophies*. As elsewhere, we will stick to the shallow end of these deep waters. The key idea is that we replace the assumption of a world of more or less stable entities—the assumption that underpins the data tables of giscience—with a world of processes, change, and events, where stable entities, understood as patterns of repeated occurrence (see Galton, 2018), become something we must explain, not something pre-given. Under the guise of *complexity theory*, this idea is consonant with thinking in the sciences more broadly, although geography along with many other disciplines continues to emphasize substance philosophy thinking in many of its tools and methods. Some of the computational tools most directly relevant to this worldview are

simulation models, which have become commonplace in some subfields in geography. Simulation models bring with them an array of technical, methodological, and even philosophical problems, some of which we also consider.

Many of these technical issues relate to a longstanding preoccupation in geography, particularly its more quantitative branches, with the relationship between pattern and process. I will suggest that whereas this preoccupation has at times been accused (not unfairly) of oversimplifying geographical thought, appropriately reinterpreted it can again be an important motif in the discipline.

PROCESS PHILOSOPHIES

Process philosophies have been a minor strand in Western philosophy since Ancient Greek times. Heraclitus is famously credited with saying something along the lines of "no one ever steps in the same river twice."[1] The point is that the river is not a fixed stable thing, but an ongoing constantly changing process. In some versions it is further suggested that both the person stepping into the river and the river are constantly changing.

Notwithstanding this venerable tradition, process thinking has been overshadowed in Western thought by substance and object philosophies. Yet, as Seibt (2018) notes, there is a continuous, if stuttering, line of development from Heraclitus, through Leibniz's monadology, and Hegel's dialectics to the authors central to contemporary process thinking, Peirce, James, Bergson, and Whitehead. This history of marginality is by contrast with mainstream Eastern philosophies, such as Daoism (see Chen, 2018), and also many Indigenous modes of thought (Sundberg, 2014), where processual thinking is often dominant (see e.g., Stewart, 2020). It is clear that Western process philosophies have borrowed

[1] It is unclear that Heraclitus ever said anything as direct as this (see Graham, 2019). If process thinking were more central to Western thought, it is hard to imagine that the source of Heraclitus's dictum would be quite so obscure.

heavily from both Eastern and Indigenous sources, and that this has been underacknowledged.

It would be presumptuous of me to generalize about diverse Indigenous and other non-Western philosophies. Having said that, and instead to generalize about Western science, it is not a stretch to suggest that its characteristic mind/body, human/nonhuman, local/global, time/space, and related dualisms are *atypical* among worldviews. For example, in *te ao Māori* (the Māori world), "[t]ime cannot exist without space, and space cannot exist without time" (T Smith, 2000, p. 56), "truth is not an objectified, definitive truth but a recognition of relationships and interconnectedness which defines the uniqueness of things and individuals" (2000, p. 59), and "all things are living" (CW Smith, 2000, p. 45). Or again, focusing on space and time to develop an alternative spatio-temporal ontology integrating Cree temporalities, Reid et al. note that,

> 1. Time can be a repeating cycle instead of a line; 2. The past and the future have agency, which contrasts with the positioning in the present; 3. Geographic entities are dynamic processes rather than fixed physical objects; 4. Time is inseparable from a place rather than merely a fourth dimension added to a three-dimensional space model (2020, p. 2335).

Elsewhere, Reid and Sieber (2020) rightly ask, "Do geospatial ontologies perpetuate Indigenous assimilation?" so it is important to be clear about my reasons for plotting what will be a Western course through process philosophy. Given my position as a Pākehā scholar within the Western tradition, I have chosen to emphasize process philosophies in that tradition, particularly the work of Alfred North Whitehead. This is *not* because I consider this particular iteration of process philosophy to be "best in class." Nor is the point to suggest that such ideas do not exist elsewhere—they clearly do. Rather I focus on this body of work because it explicitly seeks to correct dominant substance philosophy traits in Western metaphysics—traits firmly embedded in giscience. In this way, I hope that Whitehead's philosophy can provide pathways for giscience toward a diversity of approaches that are "open to conversing with and walking alongside other epistemic worlds" (Sundberg, 2014, p. 33).

The most complete description of Whitehead's process philosophy is set out in *Process and Reality* ([1927] 1978), where he proposes understanding reality as constituted by processes, and not in terms of things at locations in space-time. Bluntly, there are no such things as "things," only processes, or events, referred to as *actual occasions*. Even phenomena that appear to be concrete, stable things are constantly remaking themselves in processes of becoming. The dominance of substance/object thinking in the Western philosophical mainstream and in everyday language can make this simple idea seem willfully obscure and difficult. This impression is reinforced by Whitehead's propensity for coining new and unfamiliar terms like "concrescence" or "actual occasions," and for using familiar terms like experience and society in novel ways. Whitehead acknowledges this difficulty in *Process and Reality* when he suggests that "[w]ords and phrases must be stretched towards a generality foreign to their ordinary usage" ([1927] 1978, p. 4). Seibt (2018) notes that "Whitehead's process metaphysics is terminologically somewhat difficult to digest." Certainly Isabelle Stengers' enthusiasm for Whitehead's "free and wild creation of concepts" (2011) is not universally shared!

With this in mind, an easier place to start is through secondary accounts, and Mesle's (2008) introduction is very approachable. He argues that, far from being difficult, process philosophy is intuitive:

> Process philosophy is an effort to think clearly and deeply about the obvious truth that our world and our lives are dynamic, interrelated processes and to challenge the apparently obvious, but fundamentally mistaken, idea that the world (including ourselves) is made of *things* that exist independently of such relationships and that seem to endure unchanged through all the processes of change (2008, p. 8).

Or again:

> Some things change very slowly, but all things change. Or, to put it better, the world is not finally made of "things" at all, if a "thing" is something that exists over time without changing. The world is composed of events and processes (2008, p. 8).

In other words: We experience the world as a continuous flow of events and change, so why then would we take seriously arguments of philosophers that the world consists of static, fixed entities?

For some process philosophers this concern extends beyond the external world "out there," to the individual perceiving, experiencing subject. Not only you and me, and any other conscious entity, including animals, but even in some iterations of process thinking, seemingly inert entities like rocks. Mesle (2008, pp. 31–41) designates this perspective, "experience all the way down." Process philosophies therefore not only emphasize process but usually also dissolve Western thought's habitual privileging of the conscious human mind over inert matter, with its accompanying centering of the individual. It is here where process philosophy most obviously overlaps with spiritual worldviews that emphasize the "oneness" of all being.

Regardless of how far one is prepared to go along with these corollaries of process philosophy, seeing the world as composed of events and processes raises questions for geography in general, and giscience in particular. Whatever flavor of process philosophy we adopt, viewing events and change as fundamental makes entities we observe as more or less constant patterns of occurrence (Galton, 2018) that which *demands to be explained*, and not simply taken for granted. The entity–attribute model can at best only offer a dim reflection of a world of unending flux, and at worst completely misrepresents reality.

Whitehead is utterly scathing about the error of forgetting that the true nature of things is unending flux. He terms this "the Fallacy of Misplaced Concreteness" ([1925] 1967, p. 52), and considers it responsible for many of the ills of the modern world. Systematizing knowledge by simplifying it, so that it is expressed through the behavior of more or less static and enduring entities, when the reality is ongoing flux, change, and interaction among processes, leads to all kinds of problems. Scientific knowledge is impoverished by its balkanization into disciplinary silos studying different things, in denial of the interrelatedness of everything. In parallel, public policy revolves around systems of professionalized knowledge reliant on abstractions treated as real—the economy, unemployment, inflation, and so on—rather than as complicated

ongoing outcomes of interacting processes. Abstractions are useful, even necessary; the trouble arises when we start believing that they really exist. Importantly, Whitehead does not deny that working with concrete abstractions has been highly effective in advancing scientific knowledge. Until recently, such apparent progress probably contributed to the marginalization of process philosophy. In the 21st century faced with accelerating anthropogenic climate change and multiple interrelated other crises,[2] it is perhaps easier to take seriously his warnings about misplaced concreteness.

Whitehead makes not many (if any) recommendations about *how* to proceed differently. His philosophy is a metaphysics, an ontology describing the nature of the world. He doesn't offer advice on how to understand the world—epistemology—beyond urging us to recognize its processual nature, and our oneness with that nature. Others, drawing on Whitehead and other sources, such as complexity science (Prigogine & Stengers, 1984) and poststructuralist thought (Latour, 2004), have argued for new approaches to science, whether postnormal (Dankel et al., 2017; Funtowicz & Ravetz, 1993), real (Ziman, 2000), or slow (Stengers, 2018; Lane, 2017). All of these are congruent with process thinking. The recognition of "wicked problems" (Churchman, 1967; Rittel & Webber, 1973) where the complicated interconnectedness of problem-solving science with the messy worlds of policy, governance, and society is central, also aligns well with Whitehead's perspective.

Process, Space, Place, and Pattern

In Chapter 2 we noted Whitehead's ([1925] 1967) dismissal of the notion of "simple location" as uninteresting, but it's much worse than that! Simple location is not only boring, it is also central to the fallacy of misplaced concreteness:

[2] As I write, most obviously, the COVID-19 pandemic. Recall, too, that Whitehead was writing in the 1920s, when sounding an alarm about the downsides of scientific progress was still a minority, contrarian perspective.

> Of course, substance and quality, as well as simple location, are the most natural ideas for the human mind. It is the way in which we think of things [. . .] The only question is, How concretely are we thinking when we consider nature under these conceptions? My point will be, that we are presenting ourselves with simplified editions of immediate matters of fact. When we examine the primary elements of these simplified editions, we shall find that they are in truth only to be justified as being elaborate logical constructions of a high degree of abstraction ([1925] 1967, p. 53).

Considering the world as a collection of objects with various attributes at various locations in space may seem natural, but it is an elaborate abstraction. The apparently obvious notions embedded in giscience representations of space, place, region, and so on, and embedded in GIS, are baroque and misleading abstractions (Fisher, 1997, is one author who recognized this).

How then can we think about space, without reducing it to "the locus of simple locations" (Whitehead, [1925] 1967, p. 53), as giscience does? One starting point is Jim Blaut's paper "Space and process" (1961), which emphasizes how there can be no such thing as space devoid of process: "*every empirical concept of space must be reducible by a chain of definitions to a concept of process*" (1961, 2, emphasis in the original). On this basis, Blaut finds wanting a range of methodological approaches in geography that he argues rely on nonprocessual notions of space. Of particular relevance to giscience is that "[a]ll of these views assume that structure and process are two different things, which they are not; *structures of the real world are simply slow processes of long duration*" (1961, 4, emphasis added).

While Blaut refers to Whitehead only in passing, a more sustained engagement is found in David Harvey's *Justice, Nature, and the Geography of Difference* (1996, pp. 207–327), where he develops a relational account of space, time, and place. Of central importance is that "[s]pace and time are not, therefore, independent realities, but relations derived from processes and events" (Harvey, 1996, p. 256), so that "an understanding of process must precede or parallel an understanding of space and time" (1996, p. 258). This leads to the conclusion that

> the traditional dichotomies to be found within the geographical tradition between spatial science and environmental issues, between systematic and regional (place-bound) geographies appear totally false precisely because space-time, place, and environment are all embedded in substantial processes whose attributes cannot be examined independently of the diverse spatio-temporalities such processes contain[3] (1996, pp. 263–64).

For our purposes the key is that space, time, and place are inseparable from process.

Zigzagging through Whitehead as Isabelle Stengers recommends,[4] the aspects of process philosophy that jump out at me are its notions of what constitute things and how they can be characterized. It is striking from a geographical (and giscience) perspective that both spatial continuity and pattern are central to Whitehead's understanding of what we would in everyday language call things or objects or beings. For Whitehead all of these are "societies" of events, where events occur together in association ("extensive connection") with one another, to continually become a persistent thing, recognizable as such:

> Thus the theory of objects is the theory of the comparison of events. Events are only comparable because they body forth permanences. We are comparing objects in events whenever we can say, 'There it is again.' Objects are the elements in nature which can 'be again' (1920, p. 144).

In later work he stops referring to objects, and focuses on how events endure:

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[3] Disappointingly, he continues, "[t]he implications for the philosophy of geographical thought are immense, but I do not here have the space or time to make a place to explore them in any detail" (Harvey, 1996, p. 264) The scrupulous inclusion of space, time, *and* place suggests that Harvey is making a (rather dry, not especially funny) joke. There really ought to be a footnote leaving the details as an exercise for the reader.

[4] "[Y]ou cannot read *Process and Reality* from the first to the last page, in a linear manner, but must zigzag, using the index, being lured to come back to something you recollect but which had remained mute and now takes on a new importance, taking the leap that you have just felt is possible" (Stengers, 2008, p. 109).

> Endurance is the repetition of the pattern in successive events. Thus endurance requires a succession of durations, each exhibiting the pattern ([1925] 1967, p. 127).

Still later, pattern is also critical to how entities (understood as societies of related events) may be internally structured in more or less complex ways:

> The notion of a society which includes subordinate societies [...] with a definite pattern of structural inter-relations must be introduced. Such societies will be termed 'structured' ([1927] 1978, p. 99).

With these ideas in mind, it is worth revisiting the relationship between spatial patterns and processes (see §Relative Space in Quantitative Geography, Chapter 2). Quantitative geographers have always emphasized spatial pattern, although *pattern* is an ill-defined and slippery concept.[5] Geographers are not alone in failing to define the term: According to mathematicians Grünbaum and Shephard, "[t]here seems to be not a single instance in the literature of a meaningful definition of 'pattern' that is, in any sense, useful" (1987, p. 261). Those mathematical approaches that do exist, rely on the idea of the *symmetries* of an arrangement of geometries. Symmetries are the transformations—the translations, reflections, or rotations—of the geometries that map them back on to themselves. This definition depends on precise repetitions of the elements in an arrangement, and is applicable to settings like tiling (Grünbaum & Shephard's focus) or the design of patterns like wallpapers. In the empirical world—whether natural or social—precise repetition is rare. Rather, we observe recurrent similarities such that "we can say, 'There it is again'" (Whitehead, 1920, p. 144) and identify those similarities as things, amid what would otherwise be random noise or

[5] We avoided providing a clear definition several times in *Geographic Information Analysis* (O'Sullivan & Unwin, 2010). The lack of a clear definition of pattern is shared with cluster (see §Regionalizing Space, Chapter 5) and the concepts have a great deal in common: Both are repetitions in observations, the former based on geometry or spatial arrangement, the latter on qualities or measured characteristics.

flux. Whitehead is not offering a definition of pattern with this "there it is again" formulation, but it is a workable concept for our purposes, and also fits well with Galton's notion of processes as "patterns of occurrence, whose realizations are states or events exemplifying those patterns" (2018, p. 41).

Accepting that a precise definition is elusive, it is still possible to characterize patterns in the spatial configuration of things. Early work in quantitative geography pursued this goal (Dacey, 1964), often inspired by the central place theory of Christaller (1966).[6] The idea, since developed in much more detail in spatial analysis, is that patterns are departures from randomness, where randomness is defined as the absence of spatial biases in the locations of events or their spatial relations to one another. Bias in the locations of events are termed *first-order* effects, while biases in their relative locations are *second-order* effects (see O'Sullivan & Unwin, 2010, pp. 106–8). Respectively, these reflect overall spatial trends in the occurrence of events, and in the interactions between events whether these are mutualistic or competitive.

This framework is most easily understood in the context of *point patterns*, where points are formally referred to as *events*, and patterns are produced by mathematically or computationally defined *point processes*. The central concern of point pattern analysis and other branches of spatial analysis is the question, "what (posited) kinds of process could yield this kind of (observed) pattern?" Thus, while spatial analysis is often criticized for a naïve emphasis on instantaneous snapshots of the world (i.e., patterns), it is actually much more concerned with the kinds of processes that may or may not give rise to observed spatial configurations of events. The important thing, as already noted (see Chapter 2), is that the purpose of characterizing patterns is not the identification of patterns for patterns' sake, but for the clues to underlying processes that might have led to those patterns being observed.

[6] Apparently oblivious to more sinister aspects of Christaller's work in its relationship to the ideologies of Nazi Germany (see Barnes & Minca, 2013; Kobayashi, 2014).

For some years in the 1960s, relating particular patterns to unique processes that must have produced them was a holy grail of quantitative geography. But it turns out not to be so simple: In general the same or similar processes unfolding in different contexts may yield similar, or very different patterns; conversely, very different processes can yield similar (static) patterns (Olsson, 1969). This means—unsurprisingly—that there is no simple one-to-one relationship between processes and patterns. However, we *can* reasonably, if less ambitiously, expect there to be recurrent relations between processes and patterns, since, if this were not true, it would be hard to conceive of a geography (or any other science) that would be of any use at all for understanding the world. If there are no somewhat coherent relations between processes and patterns, then all would be chaos and all explanation would be impossible. To the extent spatial analysis and modeling are part of giscience, materials for processual computational representations (however abstract) might then already be available.

The injunction that the "[attributes of] substantial processes cannot be examined independently of the diverse spatio-temporalities [they] contain" (Harvey, 1996, p. 264) must be taken seriously here: It is after all why no one-to-one mapping between processes and patterns exists. The key is that the spatio-temporalities of processes are *diverse* not singular. Singular, reductive approaches in giscience have tended to attract the strongest criticism of other geographers, their skepticism often motivated by understandings of the world grounded in more plural process-oriented perspectives. Picking out single sets of attributes for spatial analysis is to unpack processes in a way that holistic process philosophies argue against. Processes may exhibit many spatio-temporalities, and it is necessary to recognize this in any attempt to examine processes through spatial analysis. *Local spatial statistics* were not developed with this critique in mind, and it is important not to overstate their accomplishments, but it is nevertheless worth noting their potential for revealing the multiple scalar spatio-temporalities of processes (Fotheringham, 1997; Johnston et al., 2014), especially if diverse distance metrics are deployed, including metrics that are not geometry-based (Deza & Deza, 2016).

Related Strands in Geographical Thought

Perhaps because of its terminological difficulties, perhaps because of its slightly jarring theological overtones,[7] or perhaps for its lack of any suggestions on how to proceed, Whitehead's process philosophy remains relatively obscure. I have emphasized it for its *thoroughly processual* "process all the way down approach" which shows that it is possible to think of the world as composed only of process. It also demonstrates that doing so requires thinking relationally, and also recognizing that space and time are bound up with one another.

It would be wrong to suggest that Whitehead's process philosophy carries much sway in geography. Nevertheless, an important inference from Whiteheadian and other process philosophies that *is* shared with other, more influential frameworks, is the dissolution of any clear distinction between the human and nonhuman. The human and nonhuman are the same kinds of entities, each capable of acting in the world in various ways—or if not acting, then at least of having effects. More broadly, this notion dissolves the nature–culture and mind–matter dualisms, foundational to modernist and postmodernist thought alike. Moving beyond unproductive stand-offs between rationalist modernism on the one hand, and relativist postmodernism on the other, in *We Have Never Been Modern* (1993) Latour suggested it was more useful to recognize that these share a commitment to the human–nonhuman dualism, and that this is where the problems of modernist rationality lie, a claim similar to Whitehead's diagnosis of the ills arising from the fallacy of misplaced concreteness.

Whether or not we accept the agency of nonhuman entities is a distraction here (see, e.g., Kirsch & Mitchell, 2004). Instead, I want to briefly explore another dimension to breaking with nature–culture dualisms, the notion of *flat ontology*, which we have already encountered (see §The End of Scale? Chapter 3). Assemblage theory (de Landa,

[7] Sample text: "It is as true to say that God is one and the World many, as that the World is one and God many" (Whitehead, [1927] 1978, p. 348). This aspect of Whitehead's thought kept theologians interested in his philosophy when few others were. In an odd coincidence, a major advocate of process theologies grounded in Whitehead's thinking was philosopher Charles Hartshorne, brother to geography's Richard.

[2006] 2019, drawing on Deleuze & Guattari, 1987), object-oriented ontologies (Bryant et al., 2011; Harman, 2018), new materialisms (Bakker & Bridge, 2006; Bennett, 2010; Kirsch, 2013), along with actor-network theory (see §Relations Do Not a Network Make, Chapter 6), earlier work by Donna Haraway (1991), and Indigenous thought (e.g., Stewart, 2020) can all, to some degree (rightly or wrongly), be characterized as flat ontologies (Ash, 2020). A flat ontology perspective argues that things can exist and interact and act on one another regardless of their type or scale or mode of existence. As Bryant puts it, "entities at all levels of scale, whether natural or cultural, physical or artificial, material or semiotic are on equal ontological footing" (2011, p. 279). In a flat ontology ideas and concepts, technologies, people, collectives, inert matter, places, and so on should be treated as having equality of being, and can be studied and deployed in explanatory accounts on an equal footing with one another.

This can sound strange at first, but it is consistent with how we develop accounts of how things come to be. When, for example, we seek to explain the (perhaps surprisingly rich) coffee culture across Australia and Aotearoa New Zealand, we might end up considering (among other things) the large-scale irrigation schemes on Australia's Murray River in the 1950s; U.S. restrictions on immigration from Southern Europe after the early years of the 20th century; the invention of the piston-driven espresso machine in 1945; the Melbourne Olympic Games of 1956; along with various specific local characters, cafés, and places. Each of these, whether people, machines, events, large-scale movements of people, or whatever is equally a thing that can have effects in the world and contribute to an explanation. In some other context, where something else is to be explained, we might assemble a different set of things, and emphasize a different set of relations and effects, even in the same space-time setting—again, diverse entities may exist amid multiple unfolding processes.

The provisional nature of any particular, context-specific, flat ontology might be a sticking point for anyone keen to develop universal explanations. In some frameworks, such as assemblage theory, each assemblage of interacting entities is unique, and not representative of a class of similar things: "the ontological status of assemblages, large or small,

is always that of unique, singular individuals" (de Landa, [2006] 2019, p. 29),[8] reflecting that perspective's origin in theory grounded in difference (Deleuze, 1994). This may also make more generalizable theorizing difficult. Flat ontologies can also be questioned if they are construed as a refusal to recognize imbalances in power among entities seen as operating on some kind of level playing field (see Amin & Thrift, 2005; Smith, 2005).

These wider, broadly political arguments are not a primary concern here. More immediately relevant is whether entities in flat ontologies possess internal structure. If not, then it is hard to see how they evade accusations of a willful refusal to recognize complexity in the world, or for that matter how we can approach explanation of different phenomena in the same setting by developing context-specific flat ontologies, as suggested above. Returning to Whitehead, societies of actual occasions (i.e., entities) can be intricately internally structured, since as we have seen, they may include "subordinate societies [. . .] with a definite pattern of structural inter-relations" ([1927] 1978, p. 99). Furthermore, he continues, they provide an environment in which their constituent entities can persist, and may also exist in an environment that allows for their own persistence:

> A structured society as a whole provides a favourable environment for the subordinate societies which it harbours within itself. Also the whole society must be set in a wider environment permissive of its continuance ([1927] 1978, p. 99).

Whitehead's metaphysics envisages an intricately, often hierarchically structured world. Given that societies are systems of extensive connection, the implication seems to be that hierarchical structure will be expressed spatially.

Assemblage theories are also clear on this point. For example, in *A New Philosophy of Society*, de Landa argues that assemblage theory, "starting at the personal (and even subpersonal) scale, climbs up one scale at

[8] Page references for *A New Philosophy of Society*, first published in 2006, are to the 2019 Bloomsbury Academic edition.

a time all the way to territorial states and beyond" ([2006] 2019, p. 5), which is seemingly at odds with the notion of flat ontology (see also the discussion in §The End of Scale?, Chapter 3). De Landa is careful to explain that scale is not only to be interpreted geometrically, that is, extensively in his work, but may also relate to other intensive properties of assemblages than their geographical extent. This distinction is set out in more detail in earlier work (de Landa, 2002; see also Escobar, 2007). As de Landa is setting out a philosophy of society, while Whitehead is describing an ontology of the material world, some divergence on this might be expected (compare Cox, 2021), given the spatial discontinuities across which social relations may nevertheless hold.[9] In any case, in both systems, ontological flatness is *among* entities or assemblages, not necessarily *within* them. Meanwhile, other flavors of flat ontology are more ambiguous on the matter of hierarchy and internal structure (Ash, 2020, references wider debates on this question).

Postscript: Process in General and Process in Particular

Much of this overview has been of a rather general nature. Maybe it is not so hard to accept the idea that all is process, and that permanent features are illusions. But, in practice, many things of interest are *permanent enough*—thing-y enough—that it is pragmatically useful to treat them as such. But while an earth scientist, meteorologist, or economic geographer might welcome geographical computing tools that take process seriously, it is hard to imagine a local government administrator tasked with maintaining street furniture getting excited about the idea that lamp-posts are *really* slow-moving processes. It may still be *useful* then to recognize things and processes as different aspects of geographical phenomena, even if—on some level—it is wrong.

Put another way, we may accept as true the proposition that all is process, that the only enduring thing is flux. But in particular contexts at particular times and places, we can consider particular processes as acting

[9] Or perhaps, since even virtual relations are constituted by physical connection via wires, optical fiber, electrons, photons, and so on, the apparent macroscopic discontinuities in social assemblages *are* connected from a Whiteheadian perspective.

on more or less enduring objects to change their properties while their identity persists. While accepting process in general, we investigate particular processes and their effects in contexts defined both by processes and collections of interrelated entities. This perspective underpins the simulation modeling approaches discussed in later sections.

THE PLACE OF COMPLEXITY THEORY

The title of this section refers to a paper by Nigel Thrift who suggests that complexity is "a body of theory that is preternaturally spatial" (1999, p. 32). It is thanks to this aspect of *complexity theory* that geographers of a computational bent may be surprisingly well placed to take on board the abstract metaphysical ideas discussed above.

Loosely speaking, complexity theory is a set of concepts and approaches that aims to understand the shared characteristics of *complex systems*. What makes a system complex remains poorly defined. Roughly speaking, a system is complex if it is composed of many interacting elements of several kinds. The terms "many" and "several" are vague, but complex systems are not like gases, composed of extremely large numbers of similar elements; nor are they small systems with only one or two elements. Rather they are systems of middling to large size characterized by "organized complexity," which Warren Weaver (1948) prophetically suggested might be amenable to analysis using novel computing methods. An outgrowth over subsequent decades from dynamical systems theory (von Bertalanffy, 1950), cybernetics (Wiener, 1948), and related fields such as artificial intelligence, complexity theory aims to understand how complex systems can be more than the sum of their parts, or as Anderson (1972) pithily puts it, how "more" is not simply more, but can become "different."

The notion of systems of organized complexity maps nicely onto Whitehead's societies of actual occasions or de Landa's assemblages. For example, immediately after describing assemblages as (potentially, perhaps even often) hierarchically structured by (geographical) scale, de Landa goes on to say that "[i]t is only by experiencing this upward