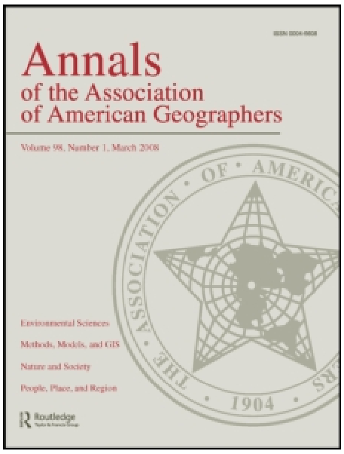

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Doing Justice to the Law

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FORUM

Doing Justice to the Law

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First, let us dispense with the issue of whether Tobler's First Law of Geography (TFL: Tobler 1970)—everything is related to everything else, but near things are more related than distant things—is indeed a law. While logicians and philosophers of science define "law" strictly and precisely, physical geographers—and, I daresay, most other practicing scientists—have a much looser, more flexible, and more catholic definition of what constitutes a law. In *Quantitative Geography*, for example, Cole and King (1968) give six definitions of "law" used in geography, several of which would apply to TFL.

The more relevant question, at least to the geoscientist, is the extent to which TFL helps us understand landscapes, climates, ecosystems, soils, and the other spatial phenomena we deal with.

TFL1: Bailey, Bones, and Butterflies

Is everything related to everything else? Strictly speaking, of course not, in the sense of direct, tracable, causal, significant links between any two objects, processes, or other phenomena. Basic principles of scale linkage indicate that (say) fluid dynamics of the atmosphere or the mechanics of aeolian sand transport are not related in any useful explanatory way to global palaeoclimatology or Cenozoic landscape evolution, even though we know that the fluid dynamics and transport mechanics operate within climate and landscape systems.

But yes, everything is related to everything else in the sense that geographical systems (simply defined here as the systems geographers deal with) are typically characterized by multiple, interrelated components and controls. Straightforward cause:effect relationships are rarely sufficient in physical geography, even at the pedagogic level. Our world is seen and analyzed in terms of maps, webs, matrices, flow charts, multiple equation systems, and other representations of multiple, interconnected, mutually adjusting objects or phenomena. Places and regions are seen as the outcome of multiple, interrelated forcings and controls and complex histories.

Additionally, everything is related to everything else in the sense that everything a physical geographer deals with is ultimately wired into the same earth system and, somewhere along the line, shares a common history. All humans (or members of other species), for instance, share a common genetic ancestor. All of us play our roles in the carbon/oxygen cycle with every breath we take, alongside other processes and entities, animate and inanimate.

Yes, widespread and long-range interrelations and teleconnections are typical of earth surface systems. Sea surface temperature or pressure anomalies in the equatorial Pacific or the North Atlantic have climatic and oceanographic repercussions around the globe. Commodity price changes in Chicago affect land use, soil erosion, and nutrient budgets on far-flung fields and hillslopes. Coastal landforms in British Columbia or New Guineau may be linked to far-away, long-ago undersea landslides that triggered tsunamis.

In physical geography the first part of the First Law of Geography (TFL1) often (but not always) applies, and is often (but not always) relevant. As a pedagogic device, to convey to students and others the complexity and interconnectedness of the planet, its credentials are impeccable. As a rule of thumb, guiding the geographer to attempt to identify and take account of interrelationships, its utility is beyond reproach.

Beyond the fact that interconnections in geographical systems may be direct or indirect, strong or weak, clear and obvious or fuzzy and vague, and relevant or irrelevant there are several different ways TFL1 manifests itself.

The George Bailey Effect

One manifestation might be named after the protagonist of Frank Capra's 1946 film (story by Philip Van Doren Stern), "It's a Wonderful Life." George Bailey, in despair and attempting suicide after a run of bad luck, and in the belief that his life has not been productive or worthwhile, is rescued by a guardian angel. Bailey is given the opportunity to see what his community would be like if he had never been born. The message is that

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the seemingly small, insignificant actions of a single person may have ripple effects and chain reactions that produce dramatically different outcomes.

The "George Bailey Effect" is a type of interconnection based on conditionality. If George does, or does not, save his brother Harry from falling through the ice as a child, then a loaded troop ship is, or is not, saved by the heroic actions of Harry Bailey later on. Conditionality is a type of contingent connectedness common in physical geography. If the surface cold air layer in a winter inversion is shallow rather than deep, then the precipitation is freezing rain rather than sleet, which may in turn result in an ice storm, the effects of which then influence forest species composition (Lafon et al. 1999). Many interrelationships in earth surface systems are conditional on factors such as fire, sea surface temperature anomalies, or the inherited effects of landform singularities (for example).

Bailey effects are common enough to produce the environmental science rule of thumb that "you can't change part of a system." Accordingly, TFL1 is translated into the First Law of Ecology: everything is connected to everything else (Commoner 1971).

Dem Bones

A traditional spiritual song, author unknown, is variously known as "Dem Bones" or "Dry Bones." It seems that no two renditions are exactly the same, but most include these verses:

. .
The foot bone connected to the leg bone,
The leg bone connected to the knee bone,
The knee bone connected to the thigh bone,
The thigh bone connected to the back bone,
The back bone connected to the neck bone,
The neck bone connected to the head bone,
.
. .
The head bone connected to the neck bone,
The neck bone connected to the back bone,
The back bone connected to the thigh bone,
The thigh bone connected to the knee bone,
The knee bone connected to the leg bone,
The leg bone connected to the foot bone,

The "bones" metaphor bespeaks a physical, mechanistic, causal interconnectedness. It may be long and complicated, but the chain of interrelationships is clear. This type of relatedness is also common in physical geography, where the complexity implied by TFL1 arises mainly due to the presence of numerous components or degrees of freedom, hooked together in long, interconnected chains of causality. Any detailed diagram of a fluvial system or the carbon cycle, for instance, should suffice to illustrate the point.

The Butterfly Effect

Many geographical systems are, or can be, deterministically chaotic. Deterministic chaos in nonlinear dynamical systems means that the effects of minor variations in initial conditions, or of small perturbations, are exponentially magnified over time. Many early and contemporary applications of chaos theory are in climatology and atmospheric sciences. The idea of tiny fluctuations being exaggerated gave rise to Lorenz's (1972) famous question/title "Does the flap of a butterfly's wings in Brazil set off a tornado in Texas?" Hence "the butterfly effect," one of the favorite metaphors of chaos and complexity theory (an interesting exercise in trivial geography and chaos theory would be to catalog citations of the butterfly effect, with a map of the different locations of the butterfly and the storm).

The relevance of dynamical instability and chaos to physical geography and its subdisciplines has been widely discussed and debated. With respect to TFL1, butterfly effects imply elaborations of both George Bailey Effects, and "bones" connections, indicating the possibility of Bailey effects that are disproportionately large and long-lived relative to the initial stimulus, and causal connections more subtle and complex than leg bones connected to knee bones connected to thigh bones would imply. The butterfly effect also implies historical connectedness via "memory," in the sense that the effects of variations or disturbances that are no longer detectable are manifest in the current state of the system.

Examples of deterministic chaos and other complex nonlinear dynamics in geomorphology, climatology, hydrology, and ecology are given by Cushing et al. (2003), Paillard (2001), Phillips (1999, 2003), Richards, Phipps, and Lucas (2000), Sivakumar (2000, Sivakumar and Jayawardena 2002), and Zeng, Pielke, and Eykholt (1993).

TFL 2: The Inequality of Other Things

The closer things are, the more related (the second part of the First Law of Geography, or TFL2), expresses the fundamental, venerable geographical concepts of distance decay and spatial dependence, which certainly predate the expression of Tobler's First Law.

Where relatedness is conceptualized as similarity, applications or tests of TFL2 are concerned with the clustering or dispersal of similar elements, the degree of contiguity of spatial features, and spatial correlation. Where "related" means functional relationships such as transportation and transformations of matter and energy, TFL2 deals with the range, distance, or area over which such processes operate and variations in their intensity over distance.

No physical geographer is likely to claim that spatial dependence or other manifestations of TFL2 operate over unlimited distances. There are finite areas or ranges over which spatial correlations occur and finite distances over which functional links operate. Much of spatial analysis in physical geography can in fact be interpreted as efforts to determine the domain of applicability of TFL2. The determination of ranges in geostatistical variograms and state probability functions, the estimation of correlation lengths in spatial autocorrelation, and the estimation of representative elementary areas and volumes are all, in essence, means for determining the distance and area scales over which TFL2 holds.

It can also be argued that defining and delineating regions—perhaps the most venerable of geographical tasks—is an implementation of TFL2. By designating areas where within-unit variability is less than between-unit variability, the principle of nearer = more related is being invoked in at least a binary sense.

All Other Things

The unspecified qualifier to TFL2, and most other laws, is "all other things being equal." In my introductory physical geography classes, I give the following as the Second Law of Geography: All other things are never equal. This is no doubt both true and strictly false in the same senses as TFL1.

The inequality of all other things is at least partly attributable to TFL1—because of the interconnectedness typical of geographical systems, it is difficult to find situations where variables or factors other than the one of interest (distance in the case of TFL2) are constant or negligibly variable. Two of the numerous examples of the problematics of the second law at work include the difficulties in establishing chronosequences (ideally, where all environmental controls are constant except for age or time), and in using palaeoclimate and palaeceological data to make inferences about future climate change (Huggett 1998; Moore 2003).

The key issue here is that not only does TFL2 have a limited range or domain of applicability in any given case, but distance decay and spatial dependence are often overprinted—or obscured—by spatial variability of other factors.

A geographical system (S), whether characterized in systems theory terms, or simply as a landscape, place, or region, is a function of the convergence of multiple general (global, or place- and time-independent) controls, and local, contingent, place- and time-dependent controls. Symbolically,

$$S = f(G_1, G_2, \ldots, G_n)(L_1, L_2, \ldots, L_m) \qquad (1)$$

where there are i = 1, 2, . . . , n general or global controls G_1, and j = 1, 2, . . . , m local or contingent controls L_j. A river system, for example, is governed by a number of spatially and temporally invariant laws and relationships involving hydraulics, fluid mechanics, the physics of erosion and sediment transport, bank stability, etc. The system is also governed by a number of time- and place-specific properties related to geologic context and history, vegetation, land use, recent and historic flood history, climate and base level change, etc. The probability of any given specific system p(S) is a function of the joint probabilities of the G_i, L_j:

$$p(S) = \int^n p(G_i) \int^m p(L_j), \quad p(G_i),\ p(L_j) < 1 \qquad (2)$$

All other things being equal for any two systems 1 and 2 requires that S1 = S2. But it is evident from equation (2) that the probability of any given S must be quite low. The G_i controls, by the nature of being general laws, may have quite high probabilities of occurring within two river (or climate, soil, ecological, etc.) systems. But the probability of any given operation or manifestation of a general law is often governed by thresholds and other conditionalities.

The probability of encountering specific local controls is likely to be very low in most cases, all the more so where historical contingency (for example climate, land use, and vegetation changes; flood chronologies; human modifications; tectonic events; etc.) plays a role.

Equation (2) makes it clear that the more factors G_i and (especially) L_j that are considered, and the lower the probability of any of them, the more unlikely any specific state S becomes. The more we attempt to actually account for "all other things," the more unlikely it becomes that all other things will be equal!

The Upshot

The inequality of other things suggests that one of the principle challenges for physical geography–and indeed all research that attempts to address the earth on its own terms, as opposed to a simplified laboratory or simulation model setting–is to integrate approaches based primarily on generally applicable laws (G factors) with those based on local, historically and spatially contingent influences (L factors). This argument has been made in the context of a number of specific areas of physical geography (Foster 2000; Fotheringham and Brunsdon 1999;

Harrison 1999; Lane and Richards 1997; Phillips 2001a; 2001b; Sauchyn 2001) and will not be belabored here.

How does this relate to the First Law of Geography? First, everything being related to everything else points in the direction of multivariate geographical systems with many degrees of freedom, and increasingly large numbers of G_i, L_j. This in turn leads to the inequality of other things and the need to condition the operation of general laws on the basis of local contingencies. Second, distance decay (TFL2) may itself represent the creative tension between the G and L factors. In one sense, TFL2 was proposed, and can be treated as, an invariant law, albeit restricted by the "other things being equal" assumption. On the other hand, applications and invocations of TFL2 are often explicitly based on determining the range and domain of distance decay and spatial dependence, thus implicitly recognizing the local, contingent nature of the spatial relationships.

We live in a world where there are indeed important and significant governing equations. But the manifestation of those equations is constrained by local conditions and varies widely. And there are no governing equations for many phenomena. Though it is often useful in specific cases to do so (and often a necessary first step), ultimately, geographical systems cannot be understood on the basis of bivariate cause-effect relationships or by reducing causal explanations to a very few key variables or factors. The First Law of Geography, and the First Law of Ecology, can be viewed as acknowledgments—maybe even celebrations—of this reality. They challenge the strict reductionist agenda, and whether or not they meet any particular definition of "law," draw our attention to the complexity and interconnectedness of geographical systems.

I suggest that the second part of the TFL can also be interpreted as a challenge to a strict nomothetic approach. "Nearer things are more related" simultaneously states an invariant general relationship in explicit terms, and almost as clearly (at least to a geographer) acknowledges the local, contingent nature of geographic knowledge. The latter is because if nothing else, TFL2 obliges us to consider whether distance alone determines relatedness (assuredly not) and whether spatial relationships hold over indefinitely long distances (of course not).

Ironically, TFL is a law that challenges a strictly law-based approach to science and to geography. By accepting this challenge, we can do justice to The Law.

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