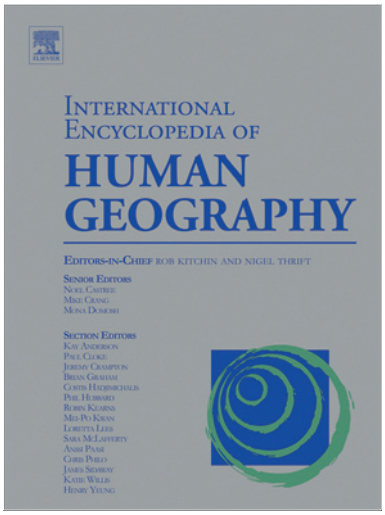

Sayre N. F, Di Vittorio A. V. 2009. Scale. In Kitchin R, Thrift N (eds) International Encyclopedia of Human Geography, Volume 1, pp. 19–28. Oxford: Elsevier
ISBN: 978-0-08-044911-1

Scale

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Glossary

Construction of Scale The process of creating observational scale.
Extent The range of measurement of a scale.
Observational Scale Epistemological moment of scale as defined by extent and resolution; the reference by which attributes and processes are measured.
Operational Scale Ontological moment of scale; the spatiotemporal attributes of a particular process.
Production of Scale The process of creating operational scale.
Resolution (or Grain) The smallest measurable unit of a scale.
Scale as Level A qualitative category defined by position on a quantitative scale.
Scale as Relation A relative framework for comparing attributes or processes through observation and relational category definition.
Scale as Size A quantitative measure of an attribute or process.

Introduction

Nearly everyone acknowledges the importance of scale in human geography, but a common understanding of what it means and how to use it remains stubbornly elusive. Articles on the subject have proliferated in the past 15 years, reflecting an effective consensus that scale belongs among such fundamental geographical categories as space, place, environment, and location. Indeed, interest has burgeoned throughout geography as a whole and in many natural science disciplines as well. Ecologists, for example, have declared scale a fundamental concept for all sciences. Yet at the same time, a plethora of definitions, uses, and theories of scale has generated considerable confusion. Common definitions of scale do not exist within disciplines, authors use scale differently within articles, and debates rage over whether scale is an epistemological tool or a material attribute of the world.

This article reviews the uses and meanings of scale in recent human geography to demonstrate the variability, complexity, and power of scale. The focus here is on noncartographic concepts of scale, yet the topic requires a brief introduction to cartographic scale for completeness. Cartographic scale refers to the spatial relationship between a map and the space it represents: it is the mathematical ratio of units on a map to units in the world. A map scale of 1: 62 500 depicts 1 mile in the world as 1 inch on the map. A small-scale map shows more area than a large-scale map, thus cartographers use the terms large- and small-scale in an opposite way to scholars in other fields. Cartographic scale is not prominent in the following discussion, but it shares a common basis with all other types of scale: relationality.

Scale has multiple meanings that are distinct yet internally related to one another. On the one hand, they are genuinely different meanings for the same term – one cannot declare one of them right and the others wrong – and in some ways they appear incompatible. On the other hand, they are conceptually linked, and the fact that they share a single term is not a coincidence. This conceptual and terminological complexity has led to frequent conflation and persistent confusion.

Fortunately, scholars can alleviate confusion if they understand scale in terms of relations and processes. The significance of scale lies in the processes that continually reconstitute it as theoretically, materially, and politically important; rather than in a particular geographical scale, such as the local or the global. These processes range from academic analysis to political border definition to road building, and each process and its outcomes change with changes in scale. This is because a change in scale represents a shift from one set of relations among processes to another. Then what is scale and how does it change? First of all, the structure of scale comprises three interrelated aspects – size, level, and relation. Size and level are relatively clear on their own, but they can obscure the fundamental aspect of scale as relation.

Scale as Size, Level, and Relation: An Illustration

To identify some salient features of scale without entangling current debates in human geography, it is useful to begin by considering another kind of scale altogether: the kind used to weigh things.

Imagine that you wish to weigh the following six items: a gold earring, a newborn baby, yourself, a truckload of waste, a trainload of grain, and the carbon emitted into the atmosphere last year. For present purposes, we ignore the distinction between mass and weight. In each case you seek to know the same quality – namely, weight – and thus all six could be expressed in one unit of measurement, such as grams. In theory, a single scale is sufficient because the weights differ only in quantity; you are abstracting from all six items in the same way.

This illustrates the first aspect of scale: as size. Whether one is measuring weight, distance, area, volume, velocity, duration, temperature, or some other quality, one uses a scale to do so. Scale as size is absolute insofar as it relies on the division of abstract weight into uniform segments for measuring particular weight. Scale in this sense is a tool, arbitrary in its units, that an observer employs to derive knowledge about the world; by abstracting from qualitatively different things in a standardized way, a scale renders them comparable in quantitative terms.

But of course you would not actually use the same scale in all six cases. The apparatuses and methods for measurement would be quite different – for example, we measure a portion of carbon emissions and estimate the total with models – and the units would also be different: grams for the earring, for example, and gigatons for the carbon. Why not use a single scale? The simple answer is technical: no single apparatus has been devised that could weigh both an earring and a train; a scale strong enough to withstand a train could not detect the weight of a single earring. One cannot put atmospheric carbon on a scale at all. We weigh different things with different scales, understood as both apparatuses and units of measurement: gold with a jeweler's scale, in grams (or ounces); humans with a bathroom scale, in kilograms (or pounds); grain with a railroad scale, in metric tons; and global carbon emissions with optical and chemical detectors and models, in gigatons. In purely quantitative terms, these different scales are separated only by orders of magnitude – all could be reduced, without distortion, to a single scale expressed in scientific notation – and each scale also represents a common order of things measurable with it. And in practice, each scale helps to constitute an order of things: gold and cocaine are very different substances, but they are weighed in the same kind of scale and expressed in the same units, and in this sense they are similar.

This illustrates the second aspect of scale: as level. Things measured in grams and things measured in tons occupy different levels of weightiness, so to speak. Note that the terms scale and level are interchangeable in this sense of scale. A scale – such as a bathroom scale – implies the existence of a class of items that can be measured on that scale, and (generally) a unit of measurement that goes with that class. Insofar as different classes can be arranged conceptually according to another, second-order scale, the first-order scales (jeweler's, bathroom, truck, railroad) become distinct levels in the second-order scale. Each level represents one of a series of regions ordered along a conceptual measurement scale (**Figure 1**). Note further that these levels are distinguished qualitatively. When we observe that the weight of the earring is on a different scale from that of a train, we do not deny that quantitative reduction is possible, but rather recognize that the quantitative difference is so great as to represent, in some significant sense, a difference in kind. Things measured in a jeweler's scale will not register on a railroad scale, and things measured on a railroad scale will crush a jeweler's scale to smithereens. Scale as level presupposes, but abstracts from, scale as size.

Technical limitations are not the only reason for using different scales in different situations. Even if a railroad scale capable of weighing a gold earring could be engineered, there would be no reason to use it for that purpose. Similarly, there is no need to know the weight of a trainload of grain down to the nearest gram. You could easily weigh yourself in grams or ounces – the way you would a newborn – but why bother? For the newborn, such precision is warranted because it can signify important differences in health and vitality, but by childhood this is no longer the case. In adults, such precision would merely generate noise, as your weight would rise and fall noticeably over the course of a day. Scales are internally related to the practical purposes for which they are devised. If gold were as cheap as grain, we would measure it in kilos or tons rather than grams. Conversely, the techniques of aggregation and measurement – including the apparatuses known as scales – can have profound effects on the practices in which they are employed. Take, for example, nineteenth-century Midwestern US grain production: the dramatic increase in corn distribution and trade due to railroad and silo technologies rapidly transformed farming.

Here we see the third aspect of scale: as relation. It concerns, for example, the relation of birth-weight to infant health (why newborns are weighed in grams), or the relation of weight to value (why a gold earring is worth measuring in grams whereas a plastic one is not). When you drive a truckload of waste to the dump, it is weighed in units suited to the interaction of the truck, the dump, and the cost of disposing of the waste. If any one of these were to change significantly – if your waste were radioactive, say – the scale would change as well. Or change might occur the other way around: if dump space became extremely scarce, or if truck scales capable of much greater precision became sufficiently widespread, then dump charges might soon be calculated per kilo or even per gram. This would in turn redound on your behavior in deciding how much waste to generate or haul to the dump.

Scale as relation abstracts from scale as level to ask why processes have certain spatiotemporal dimensions, or – put another way – what difference those dimensions make in the outcomes of processes. If scale as size is quantitative, and scale as level is qualitative, scale as relation concerns where quantitative change becomes qualitative change. A relative scale defines and orders levels based on observed relationships between processes, or entities, rather than forcing observations into

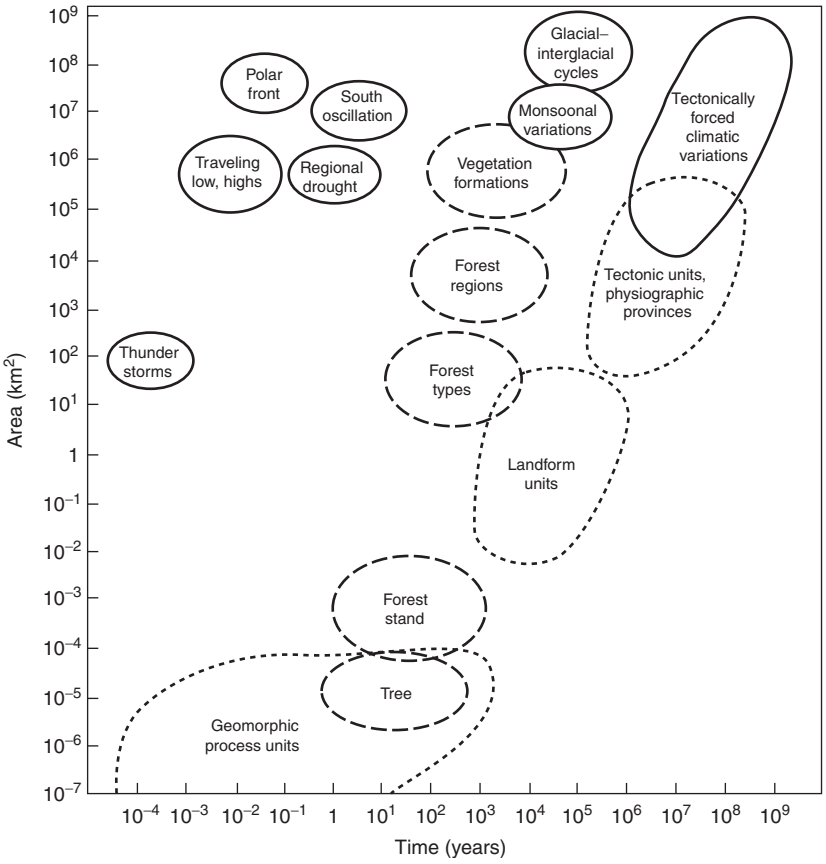

Figure 1 Delineation of conceptual levels on a quantitative scale. Solid lines denote climatic levels, dashed lines denote forest ecology levels, and dotted lines denote geomorphic levels. From Meyer, W. B., Gregory, D., Turner, B. L. II. and McDowell, P. F. (1992). The local-global continuum. In Abler, R. F., Marcus, M. G. & Olson, J. M. (eds.) *Geography's Inner Worlds*, pp 255–279. New Brunswick, NJ: Rutgers University Press.

predefined levels. The emphasis is on how entities are positioned in relation to each other. Geographers use hierarchy, network, and complex system theories to organize observations into relative scales for analysis (see below). Musical scales provide an analogy for demonstrating how relative scales represent significant changes in quality with quantity. The relations among a whole ensemble of notes define a musical scale, and a quantitative shift in scale represents a rearrangement of relations between the notes. The new scale will produce a qualitatively different set of sounds than the old. Similarly, a different arrangement of geographical levels in a relative scale will represent a qualitatively different group of processes.

Current Scale Debates in Human Geography

How does the preceding illustration help to understand scale in human geography? Table 1 summarizes the various meanings of scale discussed above. The uses of scale by human geographers in recent decades all fall into one or more of the above meanings, but the distinctions among them have frequently gone unrecognized. Often, scholars have blurred two meanings together, either in formulating their own arguments or in juxtaposing their arguments to those of other scholars. Such conflation is understandable insofar as scale does, indeed, refer to: (1) measuring phenomena – scale as size; (2) organizing phenomena into classes according to such measurements – scale as level; and (3) exploring the interactions among (processes at different) levels – scale as relation. The result, however, has been persistent confusion and occasional, unnecessary acrimony. The following overview of scale debates will highlight similarities among the various uses of scale.

Scale's Metaphysical Status

First, there is debate over whether scale is an epistemological or an ontological category. On the one hand, scholars argue that scale is simply a methodological issue. One's choice of scale may have material effects, but it does not exist independently of human observation. Many commentators have discussed the metaphors used

Table 1 The multiple aspects of scale

Scale as	*Also known as*	*Metaphysical status*	*Expressed*	*Consists of*	*Concerned to measure or understand*
Size	Observational scale; absolute scale	Epistemological	Quantitatively	Grain and extent	Weight, size, area, distance, duration, speed, etc.
Level	Conceptual scale. May be observational or operational; ongoing effort to reduce disparity between the two	Either epistemological or ontological	Qualitatively	Multiple scales-as-size arranged functionally and/or hierarchically	Different orders within one such metric
Relation	Operational scale; relative scale	Ontological	Both: where change in quantity becomes change in quality	Processes interacting across scales-as-levels; relations between scales (e.g., how to 'scale up' or 'scale down')	Scaling effects; thresholds or nonlinearities produced by cross-scale interactions; scale mismatches

to express or illustrate scale, such as pyramids, scaffolds, nested hierarchies, or Russian dolls, suggesting that scale is a figurative device or conceptual framework, not something whose reality is independent of human cognition. The focus therefore falls on the metaphors, measurement tools, and metrics employed to generate questions and knowledge about the world. For human geographers, such scales conventionally include the human body, household, neighborhood, city, metropolitan area, province/state, nation-state, continent, and globe. A research project might employ one or more of these scales; arrayed as a series, they represent qualitatively distinct levels for organizing and conducting research. For example, studies of globalization focus on economic and political processes across the local, national, and global levels; studies of childcare address personal, economic, and political processes across the individual, household, community, municipal, provincial, and national levels; and studies of the empowerment of American women examine how economic, political, and cultural practices at the household scale influence related processes across geographic levels of analysis.

On the other hand, much of the recent interest in geographical scale stems from the insight that it is not only a methodological issue. After all, geographical scales such as the household, the urban, and the national are not only measurement tools – they also refer to material and social realities. Some geographers obscure the material and political effects of spatial scale by focusing on the methodological construction of scale. What is lost is the influence of scale categories on politics, practical activity, and the material production of space. Recognition of this influence reflects a broader shift in geography from absolute to relative conceptions of space. For example, capitalism produces a historically unique material geography that scholars can readily differentiate in terms of space, economic production, reproduction, labor and industrial relations, and politics. The resulting categories, however, are relative to capitalism and would not necessarily be applicable to noncapitalist societies.

Clearly, there is truth in both positions; the two sides are implicitly referring to different aspects of scale and, consequently, arguing past each other. In terms of the introductory illustration, grams, kilograms, tons, and gigatons are human constructs that allow us to know and compare the weight of items in the world, but they are not themselves ontological categories. The observer uses a scale to measure things in the world, and this choice is principally a methodological consideration. Indeed, it is an unavoidable issue for any science: science seeks to identify and explain patterns, and this requires an epistemological reference – an observational scale.

Human geographers rarely discuss observational scale, but biophysical geographers, landscape ecologists, and other natural scientists define observational scale by extent and resolution. Resolution, also known as grain, is the smallest unit of measurement employed in a given method; extent is the overall size, magnitude, or duration over which measurements are taken. The extent and resolution of observational scale determine the patterns an observer can resolve and also influence particular observations (**Figures 2** and **3**). Finer grain studies typically have smaller extents, whereas large extents typically require coarser grains. In terms of the introductory illustration, grain refers to the precision (or smallest unit) of a scale; extent to the heaviest amount that a scale can weigh. The two tend to covary: the jeweler's scale, with a grain less than a gram, typically

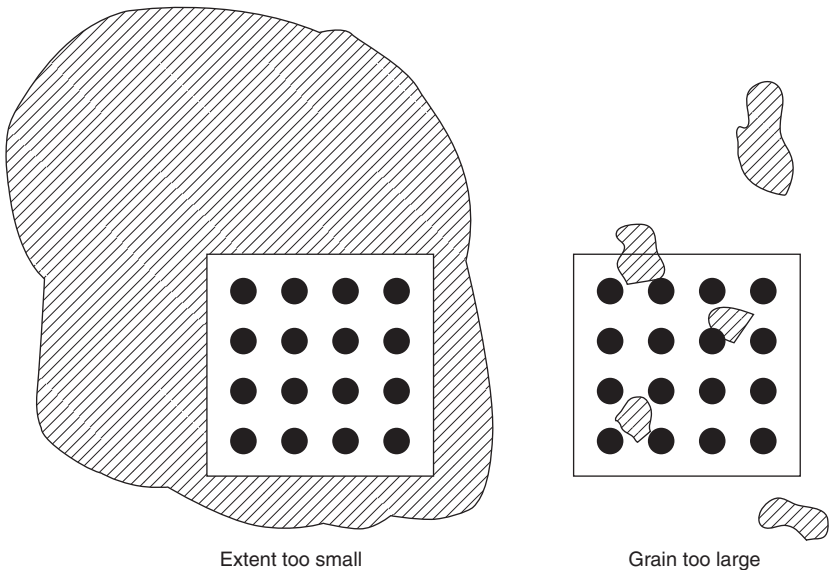

Figure 2 Grain and extent of observational scale. If the extent is too small, then the observer cannot measure the entire object of study. If the grain is too large, then the observer will not obtain data appropriate to the object of study. In both cases the observed pattern does not accurately represent the object of study. From Goodwin, B. J. and Fahrig, L. (1998). Spatial scaling and animal population dynamics. In Peterson, D. L. & Parker, V. T. (eds.) *Ecological Scale*, pp 193–206. New York: Columbia University Press.

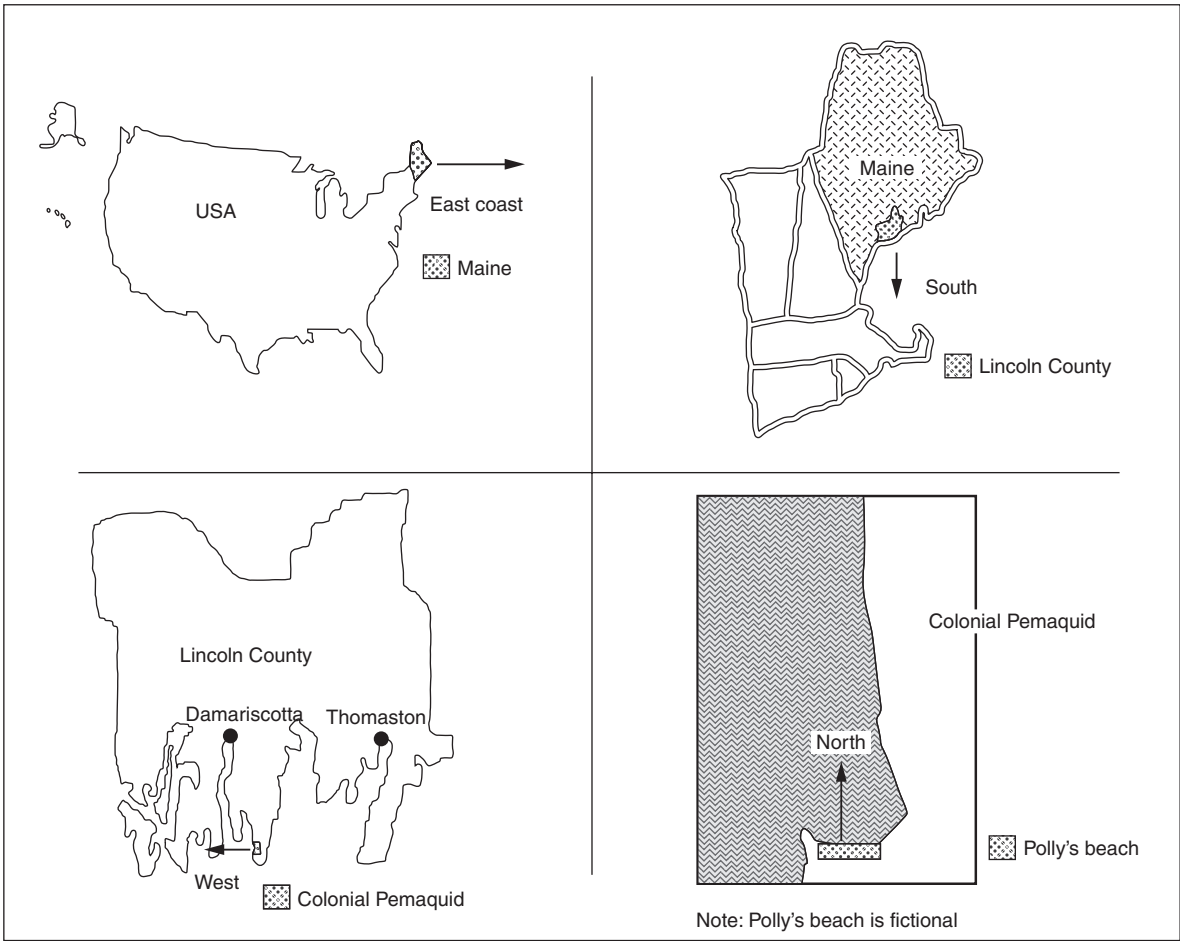

Figure 3 Choice of scale affects the observed orientation of the Maine coast. From Giampietro, M. (1994). Sustainability and technological development in agriculture: A critical appraisal of genetic engineering. *BioScience* 44(10), 677–698.

cannot weigh items of tens of kilograms or more; the truck scale can weigh something of many tons, but not with precision down to grams.

Scholars on the other side of this debate are tacitly referring to operational scale – that is, scale as an attribute or characteristic of the processes being studied, not merely as a lens or metric of observation. For processes such as governance, economic production, or social reproduction, it is clear that spatial scale can and does have profound material effects. These processes operate within bounded (if not definite) realms and have determinate (but not static) spheres of influence. For example, changes in fishery governance altered ownership, employment, and production practices in Alaska; need for childcare support created different financial responsibilities for the Canadian state, its provinces, and cities that resulted in different types of administration and support in different cities; and local economics and politics can affect global capital flows.

Operational and observational scale are distinct but related analytics: if the patterns one sees depend on the observational scale one employs, this suggests that different processes operate at different spatial (and temporal) scales. One cannot posit *a priori* the correct observational scale for a given process; rather, one must ascertain this empirically, bearing in mind that patterns may be artifacts of one's observational scale. In principle, any discrepancy between observational and operational scale should diminish over time as our knowledge and understanding of the process improve. In summary, scale cannot be understood as either ontological or epistemological: these are not mutually exclusive, nor can they be collapsed into one another. Rather, scale has both ontological and epistemological moments.

For example, Peter Taylor's foundational definition of geographical scale incorporates both observational and operational scales. His framework is an observational scale that correlates with distinctly urban, national, and world processes. Many geographers have since challenged Taylor's framework on the grounds that the scale and the processes are not fixed in relation to each other; the levels of observation and the operational extent of the processes are historically contingent. These critiques have implicitly addressed both the construction of observational scale and the production of operational scale while asserting priority of one over the other.

Scale and Hierarchy

A second point of debate concerns whether or in what sense scale is hierarchical. Taylor's framework is inherently hierarchical. The urban, national, and world levels are vertically nested and complementary to horizontal differentiation in space. Hierarchy theory does indeed provide a framework for constituting relative, second-order scales. A hierarchy of levels expresses relationships between and within distinct orders of a particular quality. The spatial hierarchy in **Figure 4** represents a four-level conceptual scale arranged by size. Each level represents a set of processes with stronger intralevel than interlevel connections. Moving from a smaller to a larger level represents a decrease in the strength of intralevel connections, and the level arrangement restricts the influence of processes at one level on those of another.

Some geographers, however, contend that relations between levels are not necessarily hierarchical (**Figure 5**). They argue that hierarchical paths do not capture the

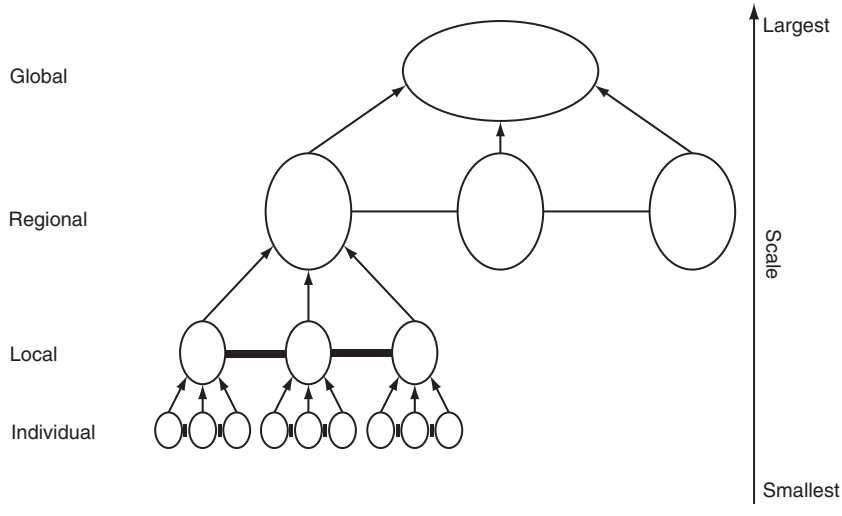

Figure 4 A scalar hierarchy. Levels higher in the hierarchy are at larger spatial scales. The thickness of the interconnecting lines indicates the degree of interaction within levels; thicker lines indicate a greater probability of interaction. From Goodwin, B. J. and Fahrig, L. (1998). Spatial scaling and animal population dynamics. In Peterson, D. L. & Parker, V. T. (eds.) *Ecological Scale*, pp 193–206. New York: Columbia University Press.

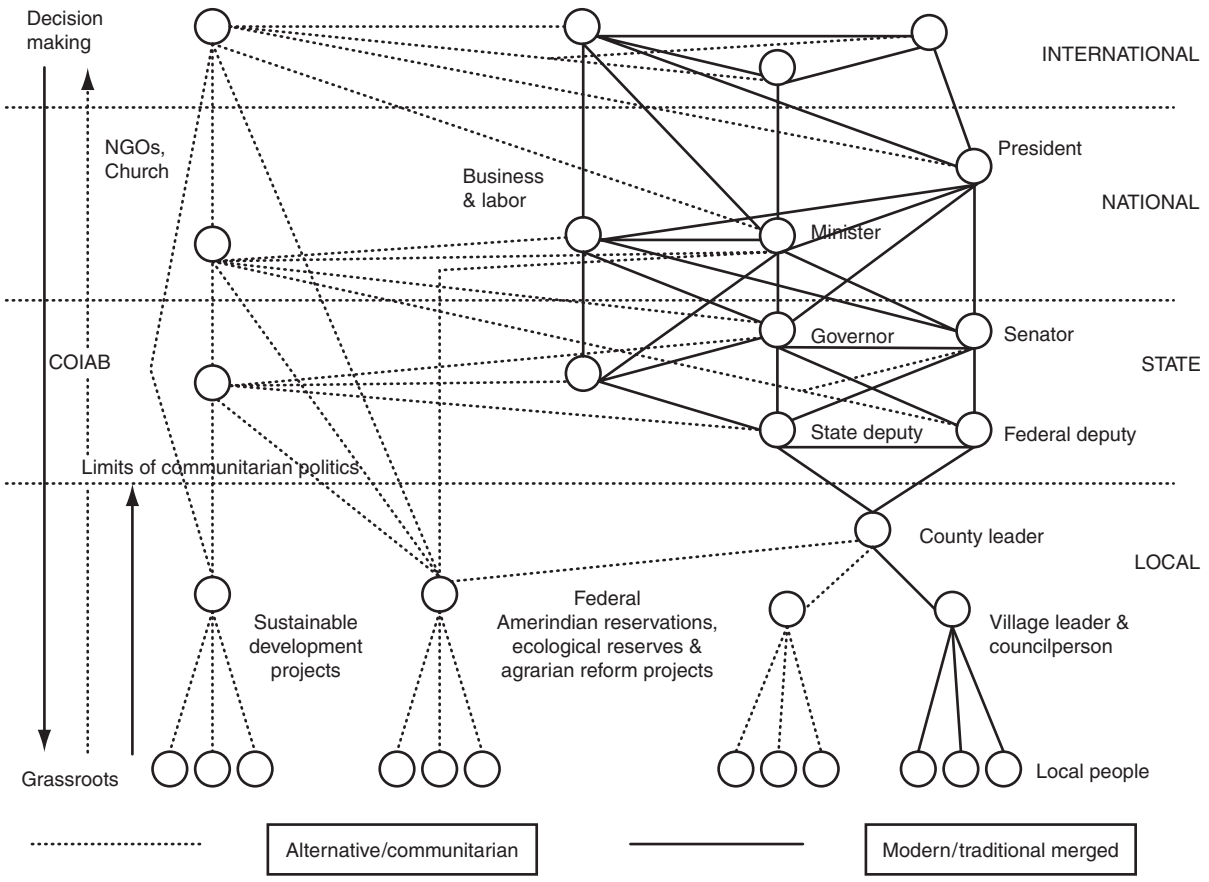

Figure 5 Hierarchical vs. nonhierarchical politics. From Hoefle, S. W. (2006). Eliminating scale and killing the goose that laid the golden egg? *Transactions of the Institute of British Geographers* 31, 238–243.

complexity and dynamics of actual interactions. Alternative models include scaled networks that span space to provide links between individual agents; and self-organizing complex systems with emergent properties that operate at particular scales. One group of scholars insists that scale's hierarchical baggage renders it ineffective and proposes to eliminate scale from the geographical lexicon.

In spite of the debate, scale is remarkably useful in all of its manifestations. Nested levels provide insights to post-Fordist patterns of globalization. It is argued that globally oriented capital accumulation has surpassed nationally organized capital accumulation in magnitude and importance, while local economics and politics have gained prominence in a global rather than national market. National policies, however, still mediate interactions between local and global processes, as demonstrated by US fishery policies that boosted local production by encouraging foreign investment. Geographers often refer to a change in dominant level of a process, such as national to global capital accumulation, as a jump in scale rather than a jump in level because such change alters the extent and outcomes of a process.

Scholars have also characterized globalization as a pattern of interdependent economic, political, and regulatory processes that continually (re)produce their own operational scales. Similarly, European transnational networks have shifted political power from the national to the municipal and regional levels. Furthermore, individual purchasing and employment behaviors, which are often gendered and personal, emerge nonhierarchically in national and global business, marketing, and production practices.

The Social Construction of Scale

The notion that scale is socially constructed is widely affirmed; indeed, it is one of the few points about scale on which human geographers are in agreement. Yet the implications of this are variously understood. Generally, scholars invoke social construction to emphasize the political significance and real-world ramifications of scale – otherwise known as the politics of scale. The point is that geographical scale is not fixed: ongoing interactions among humans in their social and physical environment create local, regional, global, etc., realms of action. The fact that people can recognize these as levels in the world

indicates that socially constructed scales have material effects and ontological status. Often, however, scholars contrast the social construction of scale to conceptions of scale as ontologically preordained – in the sense that levels of analysis are given by an immutable set of processes, independent of human cognition. This is clearly intended to compel critical scrutiny of the scales one employs in research – rather like pointing out that weighing a newborn on a railroad scale won't produce knowledge – and therefore resides in scale's epistemological moment. The confusion is further compounded by the fact that relations, unlike things, are not physical objects that one can directly observe. People constitute the national level through practice and analysis, but it can only be measured indirectly, by observing processes that operate at the national level.

To avoid this confusion, it is useful to distinguish between the construction and the production of scale. Scales are constructed in the epistemological moment, as observational scales for measurement (such as grams and tons for weight, or local and national for space). These should not be taken as ontologically given because they are not ontological at all; nor should they be taken for granted (or otherwise used uncritically) because they have important epistemological and methodological consequences. It need hardly be added that such construction is social. Scales are produced, on the other hand, in the ontological moment, as the operational scales of processes that occur independent of any act of observation. To say they are produced is to emphasize their historical specificity and contingency while allowing for both social and other determinations: insofar as they are ontologically real, these scales interact with material processes (e.g., biological, geological, and chemical) that may exceed or stand apart from the social realm.

Much of the confusion attending these debates can be traced to a failure to theorize level. This middle aspect of scale occupies a curious, polyvalent position: a level may be observational or operational, epistemological or ontological. Ecologists are more explicit in their use of the term; their levels of individual, population, community, ecosystem, landscape, biome, and biosphere are not scales at all. Rather, ecologists delineate observed processes into levels along a spatiotemporal scale based upon size and duration. Thus, they use observational scales to measure operational scales of processes, and then categorize the processes into epistemological levels. These levels are usually defined relative to their position on a quantitative scale: a biome is larger than an ecosystem, which is larger than an individual.

Geographers, however, recognize that each level, once postulated, can also define the extent and resolution of an observational scale. National level processes operate over particular areas and times that limit the observations of a national study. People construct the national level through ideology, and produce it through practice. Thus, a level can simultaneously be epistemological through analysis and planning, and ontological through praxis. Geographers observe processes at particular levels along one observational scale, and then define an observational scale for each level based upon the operational limits of its processes. The result is that national becomes both a level and a scale: the former is a level on a scale comprising local, global, etc., levels; and the latter is a scale used to analyze relations among processes operating within national limits. Studies of globalization often utilize a three-level scale – local, national, and global – to demonstrate a shift in capital accumulation from the national to the global along with a shift in political influence from the national to the local. But examination of national and local scale economic and political processes associated with Alaskan fisheries reveals the strengthening of national political power at the expense of national capital with the effect of increasing local production through foreign investment.

In short, a level can be postulated as a category for classifying and thinking about empirical phenomena, or it can be a characteristic or attribute of the phenomena themselves. Human geographers are correct to point out, moreover, that the two kinds of levels may interact and affect each other – how people think and talk about the world can affect how the world and its people are organized – into nation-states, for example.

Studies of fisheries provide good examples of the reciprocal relationship between the construction of observational scales and the production of operational scales. Geographers who study human–environment interactions increasingly characterize environmental problems as the result of mismatches between ecological and geographical scales. Processes operating at individual, population, community, ecosystem, seascape, and global levels govern fish populations; and processes operating at individual, family, community, municipal, regional, national, and global levels govern human activity. These two observational scales have similar extent, but between them the operational scales of biological, physical, and social processes often do not match (**Figure 6**). Likewise, the ecological and geographical levels do not match because ecologists and geographers measure operational scales of different processes to determine respective levels of analysis. According to this model, economic and biological collapse of human and fish populations occurs when the observational scale of research and decision making contributes to human practices that operate at different scales than those of nonhuman processes. The mismatch between operational scales of fishing based upon economics, politics, and culture; and fish reproduction based upon biology, climate, and physical environment undermines the viability of both systems. It follows that the social construction of

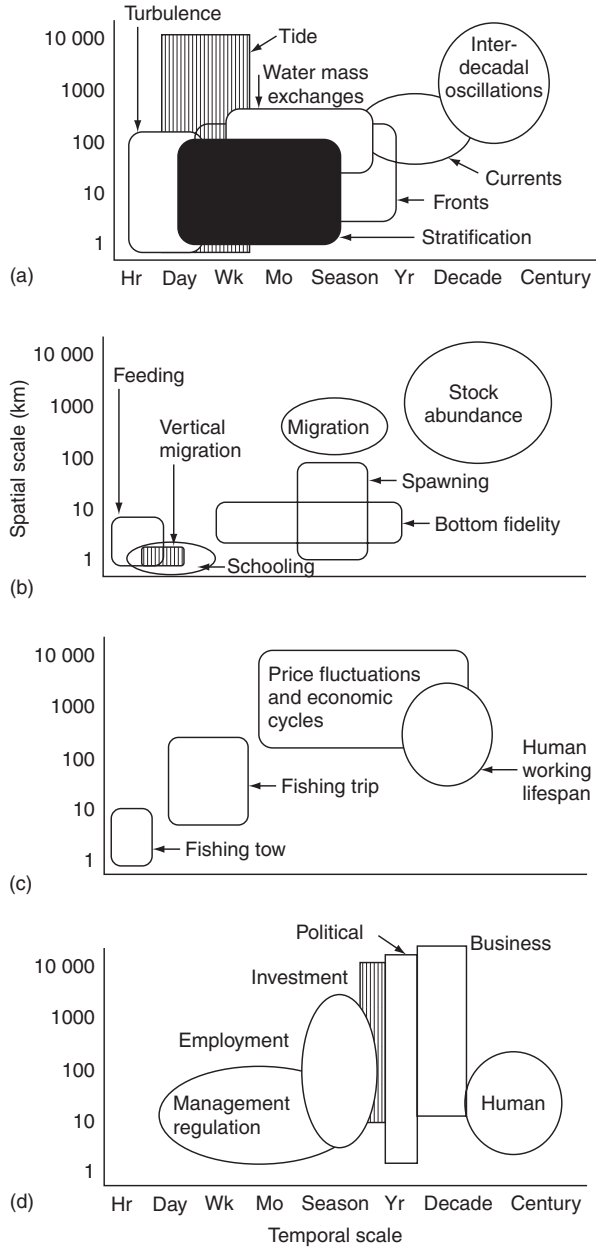

Figure 6 Space/timescale diagram of characteristic processes from the natural sciences: (a) physical; (b) biological; and from the social sciences: (c) fishing; (d) fishing communities. From Perry, R. I. and Ommer, R. E. (2003). Scale issues in marine ecosystems and human interactions. *Fisheries Oceanography* 12(4/5), 513–522.

observational scale needs to integrate human and non-human processes to match the operational scales at which coupled human-natural systems operate.

Conclusion: Processes and Relations

The many uses and meanings of scale can be reconciled if they are understood in terms of relations and processes. Ultimately, even scale as size is relational: measurement relates one thing to another to produce information or knowledge about the thing being measured. However, the scientific importance of scale lies not in measurements of size, but in exploring relations among phenomena so measured. These relations are produced by processes – hence the theoretical priority of process over scale *per se* – and both the processes and their relations are ontologically real regardless of whether they are anthropogenic or not. Processes are simultaneously spatial and temporal; there is no single correct scale for science, although any given process may have an appropriate or best scale for research. Scale has both an ontological moment, insofar as it is an immanent characteristic of material processes, and an epistemological moment, insofar as one's scale of observation may determine the patterns (or lack thereof) that one observes. Understanding these as moments of a dialectic underscores the manifold relationality embedded in scale: between subjects and objects, observers and observed, theory and practice, and knowledge and the world.

See also: Capital and Space; Complexity Theory, Nonlinear Dynamic Spatial Systems; Critical Geography; Dialectical Reasoning and Dialectical Materialism; Local-Global; Nature, Social; Networks; Relational Economic Geography; Space-Time; State Theory.

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