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Micro/Macro and Soft/Hard: Diverging and Converging Issues in the Physical and Social Sciences [1]

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Abstract

The concept of scales is widely used in social, ecological and physical sciences, and is embedded in various ongoing philosophical debates about the nature of nature and the nature of society. The question is whether the difference between scales makes a difference and if so what difference. Multilevel approaches compete with reductionist approaches. We are tracing the highlights of the disputes as well as some of the resolutions that have been offered. Most importantly, debates about differences in scale are enmeshed in what should be distinguished, namely analytical knowledge-guiding interests and those that might be called practical knowledge-guiding interests. It is unlikely that purely analytical debates can be resolved. However, progress about the impact and relevance of scale can be achieved with respect to the practical-political discursive level of knowledge claims. More specifically, scales are a crucial concept in determining the capacity for action from knowledge about the dynamics and structures of processes. For instance, in the context of climate change, knowledge claims about global and continental processes are relevant for the international political process aimed at abatement measures, whereas knowledge about regional and local effects controls decisions concerning adaptation measures.

A1.1 INTRODUCTION AND OVERVIEW

Climate scientists share a greater common understanding of the scientific usefulness of scales[2] than do social scientists[3]. This greater agreement among climate scientists does not necessarily enhance the practicality of the knowledge claims about the dynamics of the climate system. Social scientists have debated the relevance of different scales for a long time, and though the arguments have been rehashed and repeated many time, they have rarely led to new insights. Conflicts gave way to a search for linkages between micro and macro levels of analysis and the failure to agree on linkages reanimated conflicts (cf. Alexander and Giesen, 1987). The dis-

[2] For instance, in climate science, a reference to a continental scale means that only quantities averaged over a continent are considered, whereas a scale of 1 km means that variations taking place on distances much shorter or much longer than 1 km are not regarded. Similarly, a time scale of 100 and more years mean that time variations extending over intervals of less than 100 years are disregarded. The concept of scales, and the art of “filtering” dynamical equations so that they become simpler and valid to a limited range of spatial and temporal scales, is worked out formally in textbooks on geophysical fluid (atmosphere, ocean) dynamics (see for instance Pedlosky, 1987).

[3] We will refrain from extensive discussions about the terminology used in social sciences; instead, we adhere to the difference between macro and micro in the social sciences. This difference does not only (or even mainly) refer to allegedly “precise” operations and conceptions along readily quantifiable (flat or hierarchical) dimensions and therefore only time and location. It would be a mistake to conflate these two approaches, as is the case in mundane reasoning. Such a conflation occurs in a report by Ahn, Ostrom and Gibson (1998:11) where small scale “refers to phenomena that are small in regard to scales of

putes remain unresolved. We will try to reframe the issue rather than repeat claims that are invariably contested.

For the purpose of further reflection, the main points we want to develop in the process of reframing the debate on scaling is that scales—or the difference between micro and micro, as many social scientists would say—are relevant not just as an analytical problem (that is, as a problem of scientific description or explanation) but as a practical problem.

The disputes about scale have rarely been treated as a topic that ought to distinguish between knowledge-guiding interests that are concerned, on the one hand, with the practicality of the knowledge generated by science and, on the other hand, with optimizing certain theoretical and methodological conceptions in the process of generating knowledge claims (see Gibson, Ostrom and Ahn, 1998:14).

The practicality of knowledge generated by science refers to the usefulness knowledge may have as a "capacity for action" in practical circumstances and for particular actors. Analytical attributes of knowledge refer to methodological and theoretical attributes of knowledge claims, for example, the extent to which propositions developed for one level can be generalized to another level or the extent to which they can be formalized. The practicality of knowledge claims, in contrast, aims to assist actors, confronted with specific conditions of action, to set something into motion and do so, of course, with the aid of knowledge.

space, time, or quantity" and large scale "refers to big items, quantities, or space."

We maintain that there is not a linear relation or obvious congruence between enhancing the analytical and practical capacity of knowledge. Two examples may illustrate the point. (1) The determination that the “growing division of labor in society explains the rising divorce rates in advanced society” constitutes a prominent and eminent social science explanation. However, a nation, a region, a city, a village, or a neighborhood will hardly be able to “manipulate” the division of labor and therefore “arrest” (in the sense of effect) divorce rates within its boundaries. (2) The insight that the equilibrium global temperature of Earth would rise by, say, 2 degrees Celsius if carbon dioxide concentrations in the atmosphere double does not provide people at the regional and local level with the capacity to react skillfully, as this insight on the global scale provides no assessment for ongoing environmental change on a regional or local scale within the foreseeable future.

Knowledge-guiding interests that aim to enhance the practicality of knowledge claims and knowledge claims that live up to specific analytical attributes (such as logic, truthfulness, reality-congruence, etc.) are not mutually exclusive; however, they do not necessarily lead to identical knowledge claims.

The distinction between analytical and practical is particularly relevant to actors who have to deal with and convert scientific knowledge claims into practical action. Thus, choices of scale not only affect what can or will be analyzed but also what can or will be done.

But first, we need to restate and summarize the social and the physical science debate about the role of scales in the analysis and the differences that are claimed on behalf of a differentiation with the help of scales. In the case of physical science, our description will focus on climate science.

A1.2 SCALES IN THE SOCIAL SCIENCES:

A1.3 MIXING LEVELS OR WHAT IS THE DIFFERENCE?

> In every living thing what we call the parts is so inseparable from the whole that the parts can only be understood in the whole, and we can neither make the parts the measure of the whole nor the whole the measure of the parts; and this is why living creatures, even the most restricted, have something about them that we cannot quite grasp and have to describe as infinite or partaking of infinity.
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> Johann Wolfgang von Goethe ([1785]

Goethe maintains that the understanding of parts or wholes requires the elimination of their difference. It appears that the social sciences have generally followed his advice, since a liberal mixing of levels[4] or multilevel analysis is common in social science accounts. Even in approaches that are self-consciously micro or macro, linkages between levels are evident. If this is the case, then the difference between levels is unnecessary.

[4] We use the term “level” mostly as synonymous with “scale”. However, when two different types of scales are considered, for instance, space and time, they are considered to be of the same “level” if they are found to co-exist.

The assertion whether a differentiation is helpful or not is based on a certain comprehension of the constitution of examined processes and therefore to specific knowledge-guiding interests internal to the scientific community. For example, the common theoretical link that sociologists obtain between the conduct of individual actors (micro level), situational factors, or the social structure typically are a particular social psychological theory (macro level). When Robert K. Merton (1938) explains deviant behavior he does so not as the outcome of individual differences but as the consequence of the situation within which the actor is located. Merton argues that unattainable goals produce deviant behavior. Whether the actor in fact faces unattainable goals is determined by the situation or social structure. Situations vary, but the social psychology that links actor and situation (namely, trying to pursue legitimate goals) are the same for each individual. Hence the differences in location explain deviance. Without the social psychological premises, the account would be incomplete (Zelditch, 1991:102-103).[5] Put

[5] The volatility of shifting positions, courting methodological individualism but not to the exclusion of holism (or vice versa) is also one of the characteristics of classical social theory, for example, in the work of Marx, Weber and Durkheim but also in the writings of classical contemporary social theory such as Parsons (e.g. 1954:89-102, 177-196, 298-322) or in the assumptions that informed neo-classical economic discourse. By the same token, in advocating an institutionalist view, Mayer et al. (1987:13-14) do not postulate a society without people. However, they maintain that the individual is a social construction and that the linkage between institutional scripts enacted by individuals is the social psychological advocated by C. Wright Mills (1940). The institutionalist perspective corrects for excessive emphasis on the preeminent status of (individual) actors in modern economic, psychological and social theory characterized by individual socialization and internalized values.

another way, the problem is that neither solitary perspective "pays adequate attention to the constructed nature of both individuals and groups" (Calhoun, 1991:59). Part and system form a whole. The mixture of different scales is argued to be constitutive for social phenomena. Paraphrasing Wittgenstein ([1953] 1967:20, 20e), understanding parts of an ordinary language game requires the comprehension of a form of life or a cultural system.[6]

As the label already indicates, the institutionalist perspective assigns explanatory priority to the macro scale: "Social processes and social change … result at least in part, from the actions and interactions among large-scale actors … Welfare systems, job markets, and cultural structures become products of organizations or sets of organizations" (Meyer, 1987:17). Network analysis, rational choice theory, interaction ritual chain analysis (Collins, 1981) or Homans' (1961) behaviorism typically favor the micro scale. These strategies simply maintain and are linked to the theoretical premise that the realities of social structure reveal patterns of "repetitive micro-interaction" (Collins, 1981:985).

What is relevant and constitutes the immediate environment for the analysis depends on prioritizing scales. Macro models—where their own internal divisions of levels are problematic—prefer resource or ecological dependency perspectives, while micro models that acknowledge the presence of levels emphasize cultural practices and conceptions as their most relevant environment.

Approaches that readily acknowledge and freely mix different scales in their analysis place different emphasis on relevant scales, on how one progresses down or up the conceptual scale (aggregation, cumulation, interaction), and on how robust or recalcitrant different units of analysis happen to be.

The strict limitation to certain scales, that is, the conviction that levels cannot be mixed, is based on considerations of methods or access to levels. As Scheff (1990:27-28) states in an exemplary fashion: The macroworld, "so

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[6] Using more conventional sociological terminology, both "microscopic processes that constitute the web of interactions in society and the macroscopic frameworks that result from and condition those processes are essential levels for understanding and explaining social life" (Münch and Smelser, 1987:185; also Alexander and Giesen, 1987:13).

vast and so slow moving, requires special techniques to make its regularities visible—the statistics and mathematical models now taken for granted. The study of the microworld also requires special techniques, but for the opposite reason: the movements are too small and quick to be readily observable to the unaided eye." [7] Our interpretation of the elevation of one level is one necessitated by perspective: The perspective of the observer as compared with the level of the observer.

The debate about levels of analysis in the social sciences are not constrained or disciplined by commonly accepted definitions of the boundaries of disciplines and subdisciplines. However, the choice to work within the accepted confines of sub-atomic physics or cellular biology a priori limits the resolution of patterns that can legitimately be studied. Social scientists have not reconstructed the world of social phenomena in the same hierarchical fashion that is generally taken for granted in the physical sciences.

1.3.1

A1.4 SCALES IN THE PHYSICAL SCIENCES: THE CLIMATE SYSTEM

A characteristic of the physical climate system is the presence of processes on all spatial scales. The "scale" of a process is the extension of an area where the direct impact of the process is felt. Thus the spatial scale of the tropical trade wind system is several thousand kilometers; that of a cyclone at mid latitudes is about one thousand kilometers; a front, a few hundred kilometers; a thunderstorm, a few kilometers, and individual turbulent eddies in the atmospheric boundary layer exert an influence on scales of several meters and less (Figure A). A typical feature of this cascade of spatial scales is that it is associated with a similar cascade in temporal scales. Smaller scales

[7] For specifically, as Scheff (1990:28) notes, "observing the microworld requires not a telescope, such as a sample survey,

exhibit shorter term variations, whereas larger scales vary on longer time scales. For instance, a cyclone with a diameter of a thousand kilometers exists for several days, whereas a thunderstorm of several kilometers diameter is dissipated after a few hours (Figure A). A similar analysis can be made for oceanic processes.

Figure A: scales in the atmospheric dynamics.

All of these processes interact. The trade wind system, as part of the Hadley Cell, helps to maintain a meridional temperature gradient at mid latitudes, so that the air flow becomes unstable and eddies form (namely, extratropical cyclones); these storms form fronts, and the strong winds blowing above the Earth surface create a turbulent boundary layer of several hundred meters height. In this argument, large-scale features create environmental conditions so that smaller scale features emerge. This view is supported by an experiment with a complex climate model simulating atmospheric motion on an "aqua planet", i.e., a globe without topography (Fischer et al., 1991). Initiated with a motionless state, driven by equator-to-pole gradients in the global ocean's surface temperature and by solar radiation, the general circulation of the atmosphere just described emerges within a few weeks, with trade winds, extratropical storms, and turbulent boundary layers. Climate at a smaller scale appears as conditioned by the state at a larger scale (von Storch, 1999).

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but a microscope—video- and audiotapes, or at least verbatim texts, which provide the data for discourse analysis."

However, the smaller scale is not determined by the larger scale, as demonstrated by the weather details, which may differ greatly in two very similar synoptic situations (Starr, 1942; Roebber and Bosart, 1998). But information about the conditioning large-scale state is incorporated in the statistics of small scale features. This fact is used in paleoclimatic reconstructions (Appenzeller, Mann), which are based entirely on “upscaling” of local information like tree ring widths or densities.

Do the smaller scales affect the larger scales? They do: without the small scale eddies in the turbulent boundary layer, a cyclone would not lose its kinetic energy; without the extratropical storms, a much stronger equator-to-pole temperature gradient would appear and the Hadley Cell, with its trade wind system, would possibly extend to the polar regions. While the large scales condition the smaller scales, the smaller scales make the large scales more fuzzy. There is a simple intuitive arguments for this asymmetry: there are many realizations of the smaller scale process, encompassed in the area of influence of one larger scale process. The smaller scale processes represent a random sample of possible realizations, and their feedback on the large-scale process depends on the statistics of the smaller scales processes. The details of a single storm are not relevant, but the preferred area of formation, the track of the storms, and the mean intensity do influence the formation of the general atmospheric circulation.

Aside from making the large scales more fuzzy, smaller scale short-term variations also cause the large-scale components to exhibit slow variations. This phenomenon, comparable with Brownian motion of macroscopic particles under the bombardment of infinitely many microscopic molecules, is demonstrated in the "stochastic climate model" of Hasselmann (1976). The short term variations are considered random, and the large-scale components integrate this random behavior. Whether the many small-scale features are really varying randomly is irrelevant; as long as these processes are strongly non-linear, often a valid assumption, their joint effect can not be distinguished from randomly generated numbers.

This effect is illustrated in Figure B, showing the time evolution of a one-dimensional world characterized by a large-scale (global) temperature: solar (short-wave) radiation is intercepted by this world; part of this radiation is reflected back to space; the intercepted radiation is re-emitted as thermal (long-wave) radiation proportional to the fourth power of temperature. When the proportion of reflected solar radiation ("albedo") is such that a higher temperature is connected with lower reflectivity (less snow and ice) and lower temperature with higher reflectivity (more snow and ice), then Earth can have two different temperatures. Which of these temperatures is attained depends on where one starts (Figure Ba). However, a different behavior emerges when the reflectivity exhibits additional random variations, representing the variable small-scale cloud cover of Earth (Figure Bb). The systems exhibits slow variations and intermittent jumps between the two preferred regimes of the system. Obviously, in this thought experiment, the small-scale, short-term variations ("noise") are a constitutive element, causing the emergence of slow variations of large-scale temperature (von Storch et al., 2000). Time series of observed large-scale quantities, like the global mean near-surface temperature, show similar frequency behavior, even if the interesting regime shifts in Figure Bb are not obvious (Hansen and Sutera; Nitsche et al.).

Figure B: a EBM without noise, b with noise.

A1.5

A1.6 THERE IS NOTHING AS PRACTICAL AS A GOOD THEORY

Our discussion of the macro/micro controversy in the social sciences and the accomplishments of scaling in climate science has shown that, despite their divergence, the focus in both cultures is on the analytical accomplishments. That is, scaling issues tend to be deliberated and judged in the sciences based on the internal knowledge-guiding interests.

But this also implies that the scaling problem is discussed in a one-sided manner. Improvements in the analytical capacities of knowledge (or the scientificity of knowledge claims) do not always improve upon the practical efficacy of knowledge. The thesis that analytical improvements enhance the usefulness of knowledge is best captured in the maxim ”there is nothing as practical as a good theory“. The emphasis clearly is on good theory, and what constitutes good theory is disputed more in the social than the physical sciences. An improvement of theory surely constitutes intellectual progress within science. But good theory does not invariably point to “elements” in a concrete situation that can be acted upon in order to accomplish a certain purpose, for example, in the sense of affecting development of a specific process—even though that process is better understood because of the good theory (and the scaling choices made in order to generate good theory).

That good theory—and whatever good theory may mean in concrete terms—does not automatically mean practical knowledge can best be shown by defining knowledge as a capacity to act or as a model for reality (see Stehr, 2000).

Our choice of terms is inspired by Francis Bacon's famous observation "scientia est potentia," or, as it has often been somewhat misleadingly translated: "knowledge is power". Bacon suggests that knowledge derives its utility from its capacity to set something in motion. The term "potentia", or capacity, describes the power of knowing. Human knowledge represents the capacity to act, to set a process in motion, or to produce something. [8] The success of human action can be gauged from

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[8] Knowledge, as a generalized capacity for action, acquires an "active" role in the course of social action only under circumstances where such action does not follow purely stereotypical patterns (Max Weber), or is not strictly regulated in some other fashion. Knowledge assumes significance under conditions where social action is, for whatever reasons, based on a certain degree of freedom in the courses of action that can be chosen. Certain circumstances of the situation have to be actionable.

Space does not allow us to examine all the implications of our thesis. However, this much needs to be added: the notion that constraints may be apprehended as open to action or, as more or less unalterable, should not be interpreted to mean that the apprehension of pertinent constraints of action is merely a subjective matter and an idiosyncratic component of social action. Evidently, it is not only the social definition of the nature of the situation that decides whether certain features of the context in question are fixed or not. Such a conception of situational components that are open to social action of course ignores what are often called "objective" constraints of human conduct, which facilitate social action or impose on it certain limits. Nonetheless, extraneous or structural constraints that may issue from given social contexts may be interpreted in terms of "sets of feasible options" open to individuals and groups (Giddens, 1990:107; emphasis added) because such structural constraints are ultimately the product of decisions of specific actors, though the ability of many to reproduce and effect such constraints is often severely restricted. But in the final analysis, the point is, whatever the objective constraints, they are not beyond the control of all actors. These considerations require that the consideration of features of specific social contexts as either relatively open or closed to social action should not be driven solely by a subjective definition of situational constraints, but should recognize, for example, that actors at times may be largely unaware of constraints that are "actionable" (cf. Merton, 1975:173-176). Individuals and groups may therefore need and be prepared to accept some form of enlightenment. This "critical" function could well be served by a practical social science that provides a cogent account of human agency as it is mediated by the specifics of certain social contexts. In this sense, the function of social science is to open up possibilities for social action that common sense, for example, strives to conceal or manages to close down (cf. Bauman, 1990:16). For a more detailed discussion of the various implications of our thesis, see Stehr (1992).

Karl Mannheim ([1929] 1936) defines, in much the same sense, the range of social conduct generally, and therefore the contexts in which knowledge plays a role, as restricted to spheres of social life that have not been completely routinized and regulated. For, as he observes, “conduct, in the sense in which I use it, does not begin until we reach the area where rationalization has not yet penetrated, and where we are forced to make decisions in situations which have as yet not been subjected to regulation” (Mannheim, [1929] 1936:102). Concretely, “The action of a petty official who disposes of a file of documents in the prescribed manner or of a judge who finds that a case falls under the provisions of a certain paragraph in the law and disposes of it accordingly, or finally of a factory worker who produces a screw by following the prescribed technique, would not fall under our definition of ‘conduct.’ Nor for that matter would the action of a technician who, in achieving a given end, combined certain general laws of nature. All these modes of behaviour would be considered as merely ‘reproductive’ because they are executed in a rational framework, according to a changes that have taken place in reality or are perceived by society.

The notion of knowledge as a capacity for social action has the advantage that it enables one to stress not just one dimension, but the rich, multifaceted consequences of knowledge for action. The realization of knowledge in political, everyday, economic, or business contexts is embedded in a web of social, legal, economic and political circumstances. That is, the definition of knowledge as a capacity for action strongly indicates that the realization of knowledge is dependent on specific social and intellectual contexts. Knowledge use and its practical efficacy is a function of "local" conditions and contexts.

Scaling decisions can therefore be affected with respect to actionable circumstances and not merely attributes that suggest themselves because they happen to be desirable from an analytical perspective.

A1.7 THE DIFFERENCES THAT MAKE A DIFFERENCE: SCALES IN CLIMATE CHANGE AND CLIMATE IMPACT RESEARCH

The scale problem outlined above relates to both a success and a major limitation of modern climate research in constructing plausible climate change scenarios. The computing technology available now and in the foreseeable future does not allow resolution of small-scale features in climate models. Instead, the small-scale features are not described in any detail but are parameterized, i.e., their effect on the resolved scales is

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definite prescription entailing no personal decision whatsoever" (Mannheim, [1929] 1936:102).

described as a function of the resolved scales. In this way, the equations are closed, and the large-scale features are described realistically. The overall general circulation of the atmosphere is simulated as in the real world, extratropical storms are formed with the right life cycles and locations. Obviously, this success is not perfect and the next years will see significant improvements. Independently of the degree of success on scales of, say, 2000 km and more, global climate models fail to provide skillful assessments on scales of, say 100 and less kilometers.

Therefore the contemporary discussion concentrates only on anthropogenic climate change detectable now on the global scale, and not on the regional and local scale. For political purposes, namely for emphasizing the need for abatement action of the worlds' governments, these results valid for large scales are sufficient, as the details of expected change are less important than the perception of global risk.

When we consider the alternative though not contradictory poltiical strategy to abatement measures, namely adaptation, we need regional and local assessment of anthropogenic climate change, since climate impacts people mainly on the regional scales. Regional scales as social constructs are highly variable. Storm surges happen regionally; the storm track may be shifted by a few hundred kilometers; when rain replaces snowfall, or snow melts early, a catchment is affected, and so on. Such information may be derived by postprocessing the output of global climate models, by exploiting the above sketched links between the scales. For this purpose, climate scientists have designed dynamically or empirically constructed models describing the possible regional states consistent with large-scale states generated in global models. This approach is named "downscaling", as information from larger scales is transferred to smaller scales. "Dynamical downscaling" uses models based on detailed dynamical models, or regional climate models; "empirical downscaling" operates with statistical models fitted to the observational evidence available from the recent history.

While a large variety of "downscaling" techniques have been developed in the past decade, they have not yet provided climate impact research with the required robust estimates of plausible regional and local climate change scenarios, mainly because global climate models have not yet provided sufficiently converged consistent large-scale information to be processed through "downscaling" (Giorgi et al., 2001). However, one might expect that this gap could be filled in within a few years, so that detailed regional and local impact studies may provide robust scenarios of changes in climatic variables like temperature, storminess and sea level.

This information also has to be postprocessed further with dynamical and empirical models of climate sensitive systems, like the water balance in a catchment, the ecology of a forest, the statistics of waves on marginal seas, or the economy of agriculture. Of course, in many cases, this postprocessing is futile if other factors are considered in parallel to changing climatic conditions, such as changing social preferences, technological progress and the like.

These models again suffer from scale problems. Almost all environmental modeling efforts assume that the system may separated into two subsystems, one that is explicitly described and another that is considered noise, which influences the explicitly described part statistically. The explicitly described "dynamical" part is considered to carry the essential dynamics. In climate and other physical systems, the dynamical subsystem comprises all large-scale processes while the noise subsystem comprises the small scale processes. Thus, the former contains relatively few processes and the latter, infinitely many. This convenient separation according to scales can no longer be adopted in other systems, such as ecosystems or economies.

A1.8 CONCLUSIONS

In the physical sciences, discussions of scale revolve around time and place. In the social sciences, discussions of micro/macro tend to concentrate on functional relationships. The concepts of macro vs. micro and of scales in the social and in the physical science are widely used, but not without problems (see Connolly, 1983:10-44). The question is whether the difference between scales makes a difference, and if the scales matter, what difference they make. Not surprisingly, the intensity of the dispute varies by discursive field. In the physical sciences, in this case, climate science, the debate is less intense and manifests itself in more definitive knowledge claims about the impact of differences in scale.

Well-intentioned scientists focus on the analytical qualities of the knowledge claims they generate, largely because they see it as the solution to the question of “what is to be done”, without looking at how effective and practical these accounts are going to be. This can be judged to be a form of escape from scientific labor. Effectiveness and practicality are governed by prevailing social conditions. The ability to transform prevailing contexts requires, first, an examination and identification of those contextual elements that can be altered. The mutable conditions then drive decisions about scaling.

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