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Holons, creaons, genons, environs, in hierarchy theory: Where we have gone

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ABSTRACT

This paper compares and contrasts hierarchy theory and network theory, with the purpose of instructing practitioners in both fields, particularly network theorist, as to how each might relate, and translate to the other. Hierarchy theory and network theory are distinctive but twins. Network theory works its way upscale, incrementally, while hierarchy theory reaches upscale, happy to redefine situations at each new level. Both theories are distinguished from most others in their use of holons. Holons are the vehicle used in this paper to tie network and hierarchy theory together, and show how working in tandem they can advance complexity theory in biology in general. Holons are dual structures that embody contradiction in simultaneous wholeness and partness. Patten defines holons in terms of how they function, and in this way he translates across levels with explicit steps. He does this by specifying the input environs (environment) to feed creaons, the input points of holons. The output environ is fed by the holon's genon, the points of output. These steps limit the rescaling of network theory, but allow quantification all the way. Hierarchy theory is not so limited in rescaling, but it pays the price of limiting quantification across levels. Hierarchy theory reaches further upscale with set theoretic devices that make it robust across many levels. It is explicit about the categories. Networks are internally consistent and so present models, the dualities of holons notwithstanding. When inconsistency looms, hierarchy theory moves to narratives, which do not have to be consistent, as models must. In a new elaboration of holon here, hierarchy theory identifies an energy/matter half separate from a coded information half. There are three processes: creating, becoming something else, and narrating to the world; all three progress at their own rates, associated with different causalities. It all maps onto taxon, creaon, genon, and environs, emphasizing the larger unity of network and hierarchy theory. Biological and ecological sub-disciplines map onto different parts of the holon. There is also a new theory of how observer decisions are critical in holons. The move between levels that characterizes complexity causes complex systems to become undefinable. With regard to that issue hierarchy theory offers the robustness of narrative form, while network theory hangs on to definitions as long as it can. As hierarchy theory moves upscale, fixed parameters become variables and lose their constancy. In this way structures melt into behavior of some yet higher level structure. Hierarchy theory considers melting structure as being no problem, while network theory ignores the fact that just beyond its purview, structures do indeed melt. So we need hierarchy theory and network theory in tandem to make network theory bolder, and hierarchy theory more tractably quantitative.

This paper compares and contrasts hierarchy theory and network theory, as devices for pressing the issue of complex systems. Our purpose is to instruct practitioners in both fields. We also intend to show practitioners from both fields the utility of hierarchy and network approaches as duals for addressing complexity. Particularly network theorists might benefit from how the two theories relate and translate to the other. The danger is for network theorists to fail to take hierarchy theory seriously, dismissing it as a qualitative preliminary, before the real work of quantification and algebraic calculation. United, or at least juxtaposed, hierarchy theory and network theory can make unique contributions to complexity science. This paper invokes a large number of devices, so we need a thread so the reader does not get lost. Accordingly the vehicle for moving this paper forward is the holon, which will be defined

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shortly. Holons are central to both hierarchy and network theory with their models and narratives. We will show a unity between the two theories by invoking holons as we compare and contrast.

Overton was the first to introduce the concept of holon into ecology. Bernie Patten was a champion of Overton, and elaborated the notion of holon in network theory. The ideas were mature in Patten and Auble (1980) where they introduced the notions of creaon, genon and environ. The creaon is the input portal of the holon. For biological entities Patten and Auble changed holon to taxon, not necessarily meaning the standard generalized entity in biological taxonomy. Their taxon appears to be part of the concept of holon, but with less emphasis on part/wholeness that is central to the holon concept. The genon is the output portal of the taxon. The environ comes in two forms, the input environ being the part of the environment that feeds the creaon. The output environ is fed by the genon. By breaking the holon down to the processes it uses to move between levels, the network theory of Patten follows the difficult transition in an explicit way. Hierarchy theory is more focused on the part/whole duality of holons. By not fixating on the processes of moving between levels, hierarchy theory can move between levels more easily, allowing a spanning across multiple levels.

Network theory comes from Forrester (1971) type models, which have movement of matter energy on the one hand, and information on the other, in a web of interactions. Network theory often employs matrices of transitions between structures. It steps away from Forrester type models as it becomes concerned with abstract properties of the whole network using graph theoretic approaches. For instance, Ulanowicz (1997) is able to calculate the efficiency of the network, while also noting the degree of redundancy manifest in parallel connections. As these two properties of the network system are set relative to each other, Ulanowicz is able to calculate what he calls the ascendency, a measure of robustness of the system. Patten has said many times that in the end it is qualitative differences that count, not quantities in the output of networks (S. Borrett, personal communication in review of mss), so in the end hierarchy and network theory share a common goal. But network theory is quantitative on its way to the end while hierarchy theory uses qualitative devices throughout. Hierarchy theory has been identified as the theory of the role of the observer in complex systems (Ahl and Allen, 1996). It addresses how systems appear different depending on what levels of analysis is used to address them. Both hierarchy and network theory address the way that complexity needs a special approach that moves between levels. Network theory often quantifies how the structure of the holon is put together as it functions. Hierarchy theory is more qualitative in its method, and addresses appearances of the system across levels of observation.

Normal science in ecology narrows the scope so it can simply force definitions onto a deeply constrained universe, and so sidestep complexity. That is why it needs network and hierarchy theory. The theories preserve much of the complicatedness associated complexity, while maintaining a wide purview. Rosen says a system is complex if it cannot be modeled. But what to do when Rosen's challenge pertains? One posture is to slip slide between network theory and hierarchy theory. They are united in the concept of holon.

Hierarchy theory is happy to lose much ability to quantify across re-specifications, because its goal is to probe the stability of general formulations. Hierarchy theory is often more interested in instability because that indicates a change in level of analysis. Rosen (1989) contrasts system difference as opposed to system dissimilarity. Difference only feeds in new values (e.g. a new pressure, temperature or volume of a gas). Dissimilarity occurs when, as if out of nowhere, new constraints occur on the particles in the system (e.g. discrete changes in constraints on the particles when at high pressures liquefaction imposes new tighter limits). In a hierarchy theoretic maneuver, Rosen shows how to normalize the system so to move to a higher level of analysis where all gasses are seen as just mutants of each other in a continuous genetic space, the discontinuity of liquefaction of each notwithstanding (Rosen sees the terms a, b and r in the van der Waals equation, specific to each gas, as analogous to genes specific to each organism). He patches between levels by removing instability in a fundamentally new expression. Network theory explores a variable space with graph theory. Hierarchy theory moves up a level and explores the relationships between categories; if not this category then what are its sisters and how are they different? Categories can be explored with devices like contingency tables or simple lattices.

Hierarchy theory sits next to network theory, and the two feed off each other. Network theory works its way upscale, whereas hierarchy theory reaches upscale. Thus hierarchy theory pays a price of losing quantitative precision, but it gains in being stable with regard to discrete structures across many orders of magnitude, and great changes in type. Each branch of mathematics has it strengths and purposes, and each accordingly loses out on what other branches do. For instance, differential equations do a good job of plotting a system moving over a cusp, but it takes topology to indicate that in principle there is an instability over there, even if you cannot see it. Topology tells of the general dimensional form. But topology loses a lot by being so general in its specification. For instance, in topology a cup and a doughnut are the same shape, as the hollow of the cup is sucked into the cup handle. In the end you have to normalize against something, so we choose. Thus network theory and hierarchy theory are twins, where network theory enjoys quantification, and where hierarchy theory tends toward qualitative distinctions in set theory. The mathematics of network theory is largely algebraic, while hierarchy theory uses the mathematics of category theory. Both use rich diagrams to help interpretation.

Normal scientists are aware that models are compressions of experience into a set of formal relationships. In fact, that is what normal science does. Normal scientists avoid contradictions, so as to force internal consistency. To achieve that consistency models deal with a limited depth of a hierarchy, just one or two levels. But complexity scientists are aware of a prior compression, before modeling, down to interesting arenas of discourse. For instance Checkland (1981), with his Soft System Methodology (SSM), goes through an explicit compression down to a general narrative, before he ever erects a model which is the second compression down to a formal expression. The first compression throws out all other general concerns, and opens an arena of discourse, much as does a paradigm (Kuhn, 1970).

So network and hierarchy theory have different strengths. Networks invoke quantitative analyses, and are capable of calculating their way to higher levels of analysis. But there is a cost, which is a continuous accretion of quantities. Of the early ecosystems modeling efforts in the International Biological Program (IBP), Scott Overton said, "Current mathematical models of ecosystems are so complex and large it is extremely difficult to understand how the model behaves, much less to master the details of the coupling and interactions." (Overton and White, 1981). Network theory is sometimes in danger of deserving Overton and White's criticism. Hierarchy theory works more with categories, and looks for principles of categorization. The observer is always present in both theories, but is more overtly intrusive in hierarchy theory.

1. Holons in hierarchy theory

Herbert Simon (1962) wrote the seminal paper in hierarchy theory that got things going. He came from business administration, and tended to use word models. His approach had a no-nonsense