Chapter 2
Systems Research Framework

John J. Kineman

Abstract In this chapter, we make the proposal that a system is a whole unit of nature. We then propose a systems research framework, specifically the PAR Holon Framework that can yield a holistic form of systems analysis. By *whole* is meant a natural unit that is a self-related cycle of causes. The concept of systems has been around since the earliest philosophical records. To date, we do not have a widely accepted definition. The schema we present is based on the work of the mathematical biologist Robert Rosen and it follows, with important modifications, the causal and categorical definitions given by Aristotle. The resulting four-quadrant, four-category framework is then described and related to other meta-system frameworks that exist independently in many disciplines. There are two keys to understanding this framework. One is that since Aristotle we have thought of causality in a dualistic, hierarchical way, with ultimately unknowable causes at the top and inert substance at the bottom. Natural science has focused on the bottom half and humanistic and social sciences have focused on the top. Prior to Greek philosophy, however, in *nondual* philosophy, these same causes were described as a self-related cycle, giving a holographic view of reality. By reinventing the causal cycle in mathematical terms we remove the problem of *unnatural* causes. The entirely natural treatment of the four causes then lends itself to mathematical rigor and many applications in science, humanism, and other fields. Examples and worksheets are provided to help introduce the reader to this highly systemic way of thinking.

Keywords PAR Holon Framework • Systems analysis • Modeling relation • Holism • Causality • Category • Hierarchy • Duality • Holographic view

> All things physical are information theoretic in origin—this is a participatory universe.
>
> John Archibald Wheeler (Zurek, 1990, p. 5).

In this chapter, we will look at a general analytical framework for systems research and scholarship that has very deep roots and extends, in various forms, throughout science, the arts, and all of academia. Ideally, we are looking for a general way of understanding complex systems.

J.J. Kineman
University of Colorado, Boulder, CO, USA

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Considering the wide range of philosophical views about Systems (Chapter 1), and the idea of *requisite variety* (Ashby, 1956),[1] for understanding complex natural and human systems, it is natural in systems fields to employ some form of "mixed methods" research (Creswell, 2013; Halcomb & Hickman, 2015). Nevertheless, we need a way of resolving seriously unproductive divisions, such as that classically described in C. P. Snow's (1993) book, *Two Cultures*. Furthermore, a many methods approach still may not capture the essence of a complex system. In each method, especially in the sciences, our struggle for knowledge depends on translating experience into specific concepts that we find familiar and easy to grasp. This naturally sorts into specialized views, and by default, the classical view is what they all have in common. We might then wonder if the necessary variety for describing complex nature can itself be captured in a single framework or if complexity necessarily implies pluralistic views that cannot be unified. The systems sciences include many views and a wide typological scope on these issues, including a search for unity (Rousseau, Billingham, Wilby, & Blachfellner, 2016a, 2016b, 2016c).

It is important, however, to distinguish between unity and reduction. A model of unity can exist at a more general level of specificity, thus allowing for multiple kinds of special system reductions. Traditional mechanistic or materialistic reductionism, as it evolved in the modern era of science, was distillation to absolute concepts of nature, with the hope that it would prove sufficient for explaining all phenomena. Instead, it demonstrated that what seems absolute at one level may be relative at another.

A unifying analytical framework, on the other hand, might claim to be general without claiming to substitute for more specific theories. The question then is: Where do other theories fit within that general framework? Of course, whether or not the framework is truly general will necessarily remain an open question subject to testing. Still, it is the case that: "A common, classificatory framework is needed to facilitate multidisciplinary efforts toward a better understanding of complex SESs[2] [because]…entirely different frameworks, theories, and models are used by different disciplines to analyze their parts of the complex multilevel whole" (Ostrom, 2009, p. 420).

There are at least two ways to develop a general systems framework. One is to build "bridges" between diverse theories, methods, and views (Friendshuh & Troncale, 2012; Rousseau et al., 2016b; Venkatesh, Brown, & Bala, 2013). Another is to find a general pattern that is common to all systems (Falcon, 2012; Kineman, Banathy, & Rosen, 2007; Koestler, 1970). As William of Occam (1287–1347)

[1] Requisite variety refers to systemic stability and regulation. Essentially, the number of states of control mechanisms must be equal or greater than the number of states in the system being controlled. As Ashby (1956) stated, "Variety can destroy variety" (p. 124).

[2] Socio-ecological systems or social ecological systems.

famously noted, we favor those concepts that facilitate our understanding with the fewest assumptions—the principle of parsimony. Thus, the second approach is pursued for deeper understanding, economy and elegance, even though the diversity implicit in the first approach is needed to test it.

The framework discussed here was derived in the most general way possible, primarily from two sources: relational biology, which provides most of the theory in this chapter, and participatory action research (PAR), which is described in Chapter 5. The first source for the framework, relational biology, began in the 1950s at the University of Chicago with mathematical biologists Robert Rosen and Nicholas Rashevsky. Their question was, "What is life itself," meaning, what causes it, not just what it does. Rosen concluded that the answer lies in a fundamental "modeling relation" that not only characterizes knowledge in the human sciences but also represents analogous processes in nature (R. Rosen, 1985, 1991, 1999). But describing that relation requires undoing certain mechanistic assumptions about causality at the foundations of science and mathematics.

The second source for the framework, PAR, contrasts the highly theoretical approach of relational biology because PAR is an empirical framework for complex systems analysis and management in the social sciences. Relational causality turns out to be very much like a PAR cycle, although there was no connection between these developments. PAR developed empirically and demonstrated broad applicability in the social sciences, but is in need of a theoretical foundation for its broader application (Greenwood & Levin, 2006; Koshy, 2005; Khemmis, McTaggart, & Nixon, 2014; Sankaran, Dick, Passfield, & Swepson, 2001).

Nevertheless, many similar four-cause frameworks exist independently across disciplines, and it is surprising that we have not managed to "connect the dots" to see their commonality. Here we attempt to do that—to describe a general framework for understanding and interacting with complex systems.

In addition to these two sources, the framework presented here has deep historical roots. The ontology of four-cause frameworks reaches far back into antiquity. For a good account of its origin in Western Aristotelian philosophy see Lowe (2006). For deeper understanding of its origins, delve into Eastern Vedic philosophy (Loy, 1997). It is apparent between these two histories that something was lost along the way to modern times. It seems that we traded a whole view of causation for a mechanistic view, one that separated observers from observed, subjects from objects, humans from nature, science from religion, and so on. The term *law* became synonymous with "universal law," whereas post-modern science is moving toward "model-dependent" or "context-dependent" law.[3]

[3] In mathematics this condition is known as "impredicativity," meaning that a system's laws are not fully "predicated" on those of the general environment, but are at least partially determined within the system being studied.

Although prior science has clearly shown the value of deterministic models, it has also revealed their limitations. Roughly speaking, mechanisms have singular noncomplex models in contrast to complex relations that allow for emergence of novelty and even life. Despite positivistic hopes of explaining all systems within a single formal system, or the counterpoint of looking at cognitive and social construction, neither seems true alone but both may be true together. In other words, we must accept a notion of *complementarity*. We can observe that systems posing the greatest need and challenge for understanding and management today, including ourselves, are what we could call "complex" because they contain both general and self-determined formalities. Presently, there is no accepted theory that combines the two, although many instrumental combinations and coupled models are employed in practice.

To accept a theory is one thing, but scientific work demands that theory be formalized in mathematical language, which allows it to be analytically descriptive and synthetically prescriptive. In particular, we want analysis and synthesis to commute or merge. Mechanistic theory has been so successful largely because it accomplishes that commutation, but it does so for only a classical (mechanical) sub-set of reality. Being a partial analysis, its synthetic possibilities are also partial. But, for complex systems, the researcher needs a way to decompose systems into whole units that, when re-assembled, will not lose important systemic properties of the whole (Rosen, 2003).

Various ideas of whole causal structures have been proposed in the system sciences although there has been little success in integrating them. Nevertheless, some form of unity is necessarily implied by the concept of a system. While we will use the terms *whole* and *holistic*, we mean the latter because a completely whole system that is not also a fraction of something else is an analytical idealization—a perfect identity that is technically isolated from the universe. *Holistic* thus refers to having whole causal cycles in the system, while also being able to interact through partial relations with other systems. That was Arthur Koestler's concept when he introduced the term "holon" (Koestler, 1970, p. 57)—both "part and whole" at the same time.

It is important for progress that the systems sciences adopt a general framework that reaches beyond previous limits to allow for constructive processes (Funtowicz & Ravetz, 1993; Rosen, 1999). And yet, it is also important for integrity that science remains consistent with classical modes of understanding that have proven valid and correspond with the indispensable language of our senses (Schlosshauer & Camilleri, 2011). Accordingly, the framework presented here represents an *integral* philosophy within an expanded scientific worldview. The more general case seems to be that mechanisms are context-dependent and construction of observer contexts is event-dependent, leading to a principle of self-similar holism and complementary determination. Within that relation, interactions are like agreements that form common contexts, whereas independent contexts account for complexity.

Frameworks in General

We can take it as a requirement for a book about systems research that if one proposes an exemplary framework it should be *rigorous*, if not in some viable sense *scientific*. It should respect ontological and epistemological principles and follow a defensible logic that is justified at some foundational level in mathematical philosophy, arguably the common language of science. In this case that requirement necessarily takes us to the most general level, the logic of categories and causalities. That arena has been heavily debated since Aristotle's famous discourses on those subjects (Barnes, 1984). Indeed, at this level, a fundamental way to frame reality is conceived. In doing that, modern science took its shape by choosing and selecting certain causes calling them *real* while rejecting others. Revisiting those choices is necessary if we are to reframe our worldview more generally and systemically to account for phenomena that could not be explained in the previous way.[4]

Frameworks are commonly adopted as heuristic ways of organizing a practice or study to learn and/or problem-solve. They may be ad hoc or, more recently, algorithm-based optimizations (Lee & Geem, 2005). Our framework, based upon relational biology and PAR, begins with general principles attributed to a supposed logic of natural relations, including human experience. There is no general requirement of frameworks, of course, that they should be *natural*, and studies routinely devise arbitrary ways of looking at problems. It is appropriate, for example, to develop a framework around policy or client drivers, or various other qualities of desired outcomes on a purely instrumental basis. However, if the framework we choose is general in its reference to nature *writ large*, it should be consonant with all of these cases. Furthermore, if it is applied even retrospectively, it should be able to add value to a study or practice, under the assumption that natural organization (which, the framework presumes to be real) is more likely to give us an appropriate model. This view assumes that our concept of nature is in some sense valid, thus acting in this manner also serves as a test of the framework's general validity.

The framework presented here answers the need for an analysis that allows for the most complex condition of a system, where contextual and dynamical causes have equal freedom. That is, we want to be able to analyze the *organization* of a system in terms of relations between context (e.g., dispositions) and actualizations (e.g., dynamics). It is a matter of empirical science to decide which aspects of a given system have been reduced to one or the other, and thus which aspects of the framework can be simplified. This follows a general rule in science to not classify too early.

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[4] The reader may notice that we are using the idea of framework in much the same way as worldview, yet a mathematically explicit worldview.

Relational Holon Framework

Figure 2.1 is a graphical representation of the relational *holon*—the theoretical framework that we propose for systems research. Ontologically, it is a complementarity between measurable aspects of a system—the actualized[5] aspect, A, with solid arrows, and the contextualized aspect, C, with dashed arrows—made explicit as a whole by reference to Aristotle's four causes (Falcon, 2012). Aristotle's causes are considered *metaphysics*, in addition to substance and identity, which are concepts of understanding the fundamental nature of the world. Aristotle's four causes are material, formal, efficient, and final. Recall that a phenomenon's material cause is its physical properties; its formal cause is its structure or design; its efficient cause is its agent for being; and its final cause is its purpose for being. In Fig. 2.1 these four causes are labeled in the four quadrants of the relational holon. The cycle of causes enable structure (*s*) and function (*f*) epistemology. In the next section of this chapter, we will show its relation to PAR, which has essentially the same structure. The arrow and symbol conventions are explained later in this chapter, in the section, "Using the PAR Holon Framework."

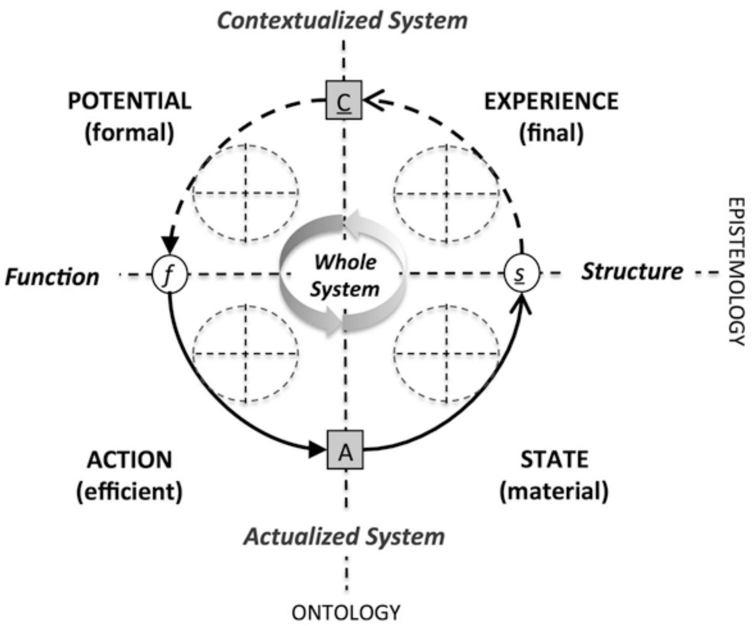


Fig. 2.1 Relational holon

[5] The term "actualized" is used instead of the more common term in relational biology, "realized," because with the introduction of the contextual category, both interactive and latent aspects are considered "real."

Holarchical organization, like that found in fractals, is implied by the four sub-holons in each of the quadrants of the diagram. These sub-holons can replace each quadrant (either as internal sub-units or external super-units) at any level. In other words, if the main cycle represents a given system, each causal aspect of that system is explained by another similarly holistic cycle; then the two cycles are said to be "closed" within one of these quadrants. The holon can thus be composed and decomposed in self-similar models.[6]

An important aspect of the diagram is that it relates *causality* and *inference* giving an explicit representation of Aristotle's concepts of "cause" and "explanation" (Falcon, 2012). We will show how this schema can be used as a consistent method of analyzing whole systems in terms of whole systems.

While providing a holistic analytical method for complex systems, it is apparent that this relational holon framework also represents a new scientific worldview. Interesting as that is, most systems researchers are concerned with relevance. It is for that reason that we note how extensively this causal structure appears to be empirically confirmed in many disciplines and cases, each with its own interpretation of the archetypical quadrants and their combinations as categories of entailment and relation. We will review the worldview implications and some examples of the framework in use.

PAR Holon Framework

The first, and perhaps most important, framework we should examine is used in PAR (Chapter 5). The relational framework represents a theory of natural causation, while PAR is an empirically derived practice that works the same way through human agency. PAR is a method of interactive or participatory research and social change. It is primarily goal directed: to intervene in a system and alter it in some way, or to study how systems change. The PAR cycle shares the same basic causal organization with the modeling relation discussed above, typically expressed as a cycle of Planning, Acting, Observing, and Reflecting.

The correspondence of the PAR cycle with Aristotle's causes is obvious when both are viewed as a cycle in which material ends become final exemplars:

PAR		**Aristotle**
Reflect	=	*Final*
Plan	=	*Formal*
Act	=	*Efficient*
Observe	=	*Material*

[6] A holarchy is thus an invertible hierarchy of inclusive wholes.

Any of these four agencies may set up another cycle. Figure 2.2 shows a typical, iterative PAR cycle where new cycles result from action and each cycle is identified by new observations. Hence, it characterizes an action research cycle. Similar iterative loops can occur for observing, reflecting, or planning. Participatory research, or intervention through the development of new information, might be best characterized by iteration based upon observation and interaction. Similarly, planning and visionary cycles can be described. The difference is in which quadrant one iterates. All four aspects are always present in all iterations, but the point of bifurcation establishes a researcher's intervention point, which identifies the program or what kind of intervention the researcher is applying (one of the four possible decompositions of Fig. 2.1). Through this, we can see that PAR analysis is enhanced by understanding the nature of the holon and its logical implications. In the following, we explore more possibilities.

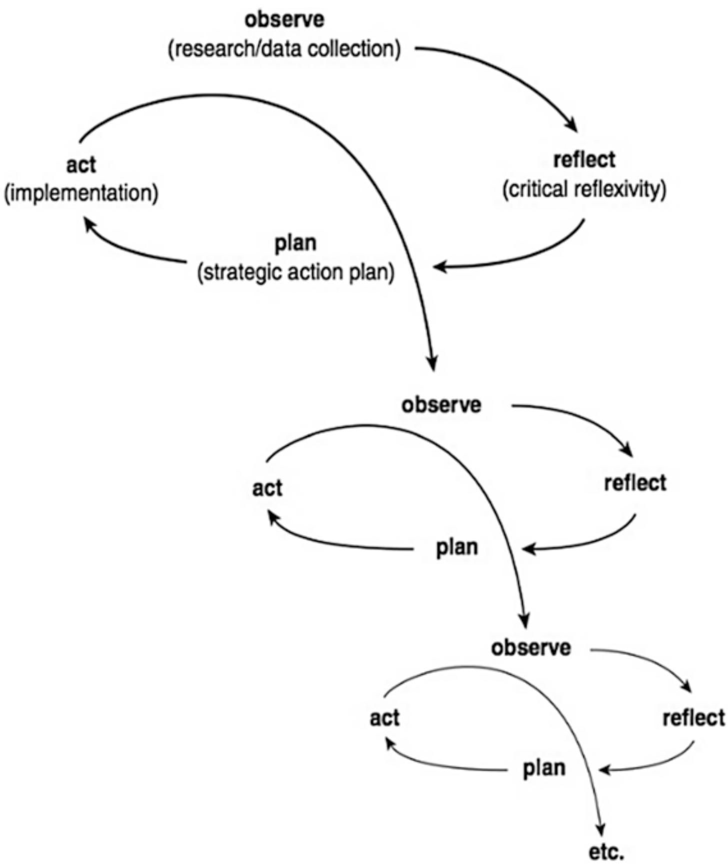


Fig. 2.2 Cycles in action research (O'Leary, 2004, p. 141)

The common PAR quadrant labels (Reflect, Plan, Act, and Observe) are applicable in cognitive/social cycles, but they are also instances of more general archetypal causalities (Fig. 2.3), suggesting a worldview of agent-like organization at the root of complexity and life, where the basic relation can be taken as a fundamental unit of natural analysis. Thus, as researchers, we are observing the same kind of organizational system by which we are conducting the observation. We do not need to assume that what nature is doing is, in principle, any different from what we are doing. In Rosen's (1990) view, assuming the same organization is the essence of true modeling in which models should be entailed (i.e., organized) like the system they model (R. Rosen, 1991). However, this framework does not insist on that correspondence; at a given level it can also relate simulations and analogies.

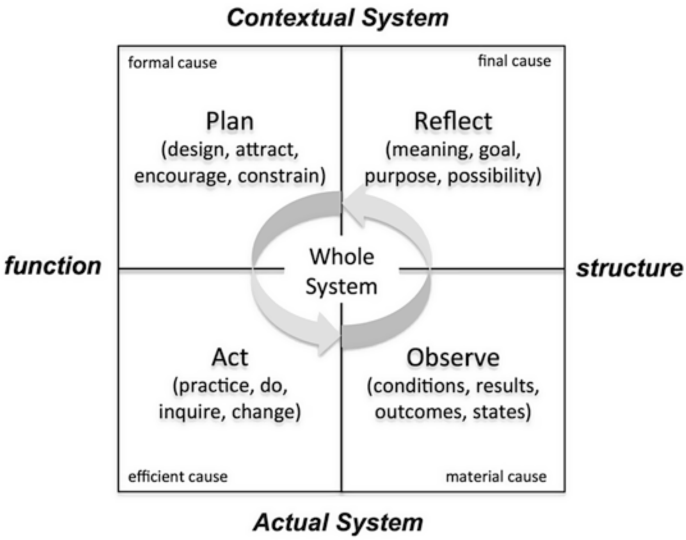


Fig. 2.3 PAR Holon Framework

Now, a brief, intuitive explanation of the four quadrants is important, not because there is anything difficult about it, but because we have not been trained to think this way.

Observe

Beginning with the lower-right quadrant in Fig. 2.3 we, as researchers, have sensory objects of perception—what we can observe. As we now know, observation is an interaction which can affect the object being observed, known in science as the *observer effect* (not to be confused with Heisenberg's uncertainty principle identified in 1927). Generally, we can say that any interaction is like an observation in that it establishes or abstracts a state of the object. Hence, this quadrant explains things in terms of what can be measured about them and the terms of measurement for the system.

Act

If we ask, thinking inductively, what governs the measurements we might receive, we reverse the cycle to the lower-left quadrant, which is action. It is action, Aristotle's efficient cause, which explains the occurrence or abstraction of states within a system; that is, action in nature and the action of observing itself. In fact, these two seem to be in a competition, where less frequent observations than natural interactions will reveal uncertainty and, vice versa, relatively frequent interactions establish mechanisms.

Plan

Continuing to reason and moving backwards around the cycle, we ask what explains the occurrence of efficient agents or forces. In this case, we arrive in the upper-left quadrant where formal boundary conditions or potentials for existence regulate the amplitude or scope of efficient causes. This is Aristotle's formal cause (although there has been much confusion about its position in the hierarchy). A very simple example in biology is niche dynamics, where the niche acts as a potential for existence, constraining, and regulating dynamic niche actualization. An example in physics is the curvature of space–time and the various constants we typically assume are absolute until we find cases where they vary (as in relativity). This quadrant is the expression of a modeling context or the conditioning in a social situation afforded by the character of the gathering, room, building, art, country, and so forth; all of which *culture* or *inform* what is thus encouraged or discouraged to happen in the discrete world of behaviors, also known as norms.

Reflect

Continuing, we can ask what explains such formative potentials. This takes us to the upper-right quadrant where we find the historical effect of previous configurations, which might be analogous to systemic experience. This is the effect of exemplars, visions, ideas, intuitions. They are as physical as any of the other quadrants, and far more intuitive than has been assumed in the many rejections of *final cause*. The evolution of organisms is predicated on previous organisms serving as exemplars for the next, via contextual encoding (variation and selection). A new invention is predicated on some vision of an old one. A recipe for biscuits probably came from some previous example. Written narratives in books may be based upon folklore. If we go on to ask what explains this quadrant, we arrive back at objects actualized before. As thinking beings we may find it easier to understand the cycle in such reverse direction, which as Aristotle saw, is the answer to "why" questions.

Cycles of Entailment

In both actual and contextual halves of the holon diagram in Fig. 2.1, we suppose causality (or inference) can be mapped as a mathematical entailment. Entailments are explained in detail in Chapter 4. Basically they are very flexible causal propositions such as the reason for some change. For example, what compels or motivates action and/or direction? An efficient entailment in the actual system is a dynamic change. But the mystery involved in the holon cycle exists in the contextual entailment, which is not commonly graphed, even in relational theory.[7] The problem is basic: We accept the concept of a *force* resulting in a new state (this was once considered "spooky action at a distance"), but do we understand how a state can establish a new force? Or, as Schrödinger described the problem, which he considered fundamental to life, how does an "inertial object" become a "gravitational object" (i.e., an *agent;* R. Rosen, 1999; Schrödinger, 1955)? Nothing in modern science explains it, except that natural objects clearly do both.

Those willing to grapple with this thorny issue tend to decide between two possible answers. In one sense we can say that there are no objects as such, they are all part of a whole system with all four aspects; so naturally, the state is correlated with and *carries* a function. But there is a more analytical answer: that a structure, when placed into a context, will induce a function *from the context*, just like a grain of sand (or other perturbation) placed in an oyster induces functions that produce a pearl. Or, a tool will have different uses in the kitchen than in the shop. Generally speaking, objects impregnate context and it is from that *inverse (or converse)* of the efficient map—the *contextual or final entailment*—that we get new functions. This principle is not restricted to living or cognitive systems, as we see in the quantum and cosmological world, where there is a two-way relation between interactions and the coordinate space in which they occur. This different kind of entailment will be discussed in Chapter 4.

[7] It is technically defined as an "inverse entailment."

Describing Organization in Systems

With this cyclical-cause view of a system expressed as entailment, it is clear that the contextual causes comprise a new area of research that has been difficult to introduce and explore. It appears today in concepts like "dispositions" (Mumford, 2003); the idea of "affordances" (Chemero, 2003); in a wide scope of literature about "control theory" in cybernetics (Åström, 2012; Chapin et al., 1997; Corning, 2001); the subject of "boundary conditions" or the "boundary value problem" (Cziko, 2000; Kelso, 1995; Wiens, Crawford, & Gosz, 1985); and "potential theory" and "function spaces" (Adams & Hedberg, 2012; Doob, 1984; Triebel, 2010), although most treatments of the latter tend to be somewhat nongeneric in that they are restricted to value limits of differential equations. Much of this discussion comes under the heading of *self-organization* (Ashby, 1947; see also Kauffman, 1995), in which order arises from local interaction between parts of a system and involves *causal loops* or cycles.

A cycle of causes can also be reduced to simpler cases, that is, to mechanisms, by assuming a fixed formal context (a complete set of natural laws). Or, it can be focused on contextual (i.e., subjective or otherwise nonlocal) qualities that may support constructive processes as experienced (Chalmers, 1996; Hameroff, Kaszniak, & Chalmers, 1999; Searle, 1992). We should understand that this latter case, outside of its relation with actualizations, is also a reduction. It has been problematic to many natural scientists for this reason: it seems to represent *form* without *substance* (like an ecological niche for bears, with no bears; or goals and plans not yet implemented in the world). However, in both cases, that is the reduction to mechanisms or niche-like affordances, the complementary domain remains theoretically present; it is simply ignored as adding no important variation. Furthermore, the relation between context and actual need not be immediate; the contextual influence (to reveal where we are going and call it a "model") only sets in motion the dynamics for its realization in a spatio-temporal domain. The framework is thus inclusive and consistent with these opposite views; yet, it also allows a study of how they may be related.

For example, we can imagine future technology without yet knowing how to build it. We can describe an existing object or its behavior without the complexity of explaining its existence. But neither one of those views alone characterizes a complete system. They are *fractions* of a system (R. Rosen, 1978), and most of modern science—from natural to social—has chosen between these fractional views, focusing either on measured or experienced realities. Scientific unity, an elusive goal, depends on what aspect of a system is to be objectified (natural science) or represented (social science).

The focus can be on a "third" alternative: *objectifying relations* between context and action. Needless to say, there can be a great deal of controversy about this view, but we are obliged to adopt a holistic view by our experience with the natural and human world, which hints of such organization. Just as physicists were compelled to accept uncertainty over a 100 years ago, today we must grapple with complexity. While it is extremely important that the framework we propose follows the mathematical logic of causal order, it is second to its correspondence with referents in nature. In other words, we put the science first and understand mathematics as a language of science.

Anticipation

We can now ask, "In what way is it 'natural'?" Inspection quickly reveals that the two sides of a modeling relation represent models of past and future. Everything that we call *actual* has already occurred, and everything we represent in an un-actualized model is yet to occur. Traditional science has given primacy to models of the past, assuming they are generally predictive of the future. Here we do not dispense with that view as one option, but broaden the schema to allow for systems more driven by models of a possible future. The information relations (encoding and decoding) thus represent *now*; a concept that is not commonly formalized. *Now* occurs in the relation between past and future—the acts of *being and becoming*. Arguably, *now* is all there really is in nature, except for models of past and future, both of which are encoded in the present. The framework succeeds in being natural in the sense of representing an active present situated between models of past and future.

Previously, scientists have not thought of *participation* (less so, *anticipation*) as a general principle; and consequently, our traditional view of nature from modern science does not include it. But it should be clear that we cannot get away with formalizing participation strictly for the case of human consciousness, because the principle itself was discovered rather indisputably at the foundations of physics, by far predating not only humans but all life that is even conceivable. Relational theory allows for the phenomenon of participation and its living consequence, "anticipation"—acting in relation to a future condition that is represented in some way in the present (Nadin, 2010; J. Rosen & Kineman, 2004; R. Rosen, 2012; see also literature on purposeful or purposive systems, Ackoff & Emery, 1972; Giampietro, Allen, & Mayumi, 2006). To the extent that a system actualizes its anticipations, which have the effect of models, it is a participant in a greater system that must, in some way, incorporate its corresponding behavior. Thus anticipations become reality.

The Importance of Context

Of course, the question we must address is how the framework can help systems research. As such, it represents a qualitative approach within which researchers may consider the organization of a system and therefore the regulation of quantitative processes by contextual conditions. It does not directly indicate what those quantitative processes are; that is a separate matter of empirical study. Yet, it allows us to consider what kind of topological space they can occur in, and by what means their determinations affect the topological space (contextual order). Thus, a researcher can analyze the relational organization of context and dynamics using available models for each. For example, physical and chemical laws at the molecular level may be involved in protein folding, but nothing in those laws can account for the contextual conditions ("top-down causation") that make protein folding and activation possible in the first place (Dill & MacCallum, 2012); yet, those conditions are established by the system. Another example entails Newton's laws of motion, which may apply in inertial frames of reference, but they do not account for scale change (relativity) under uniform motion; and yet, local dynamics establishes the relativistic context (Einstein, 1924). Similarly, the dynamics of co-workers in a corporation may depend on the values and designs that characterize the corporation and to which those dynamics may or may not contribute (i.e., a possible basis for analyzing unhealthy and healthy organizations; Cochran, 2015).

As Mumford (2003) and Chemero (2003) emphasized, dispositions and affordances—the effects of context—are everywhere in science, in all disciplines. They are nature's tendencies. The first thing we must realize in framing our approach to complex systems is that we cannot describe dispositions with the same formalism used to describe dynamics, except in special cases. These complementary aspects of a system must be represented in their own right, co-informing each other.

By considering contextual effects of a system as naturally related and constructed with dynamical behaviors in the system, the framework draws attention to *system wholeness* that may be maintained or disrupted, allowing a system to sustain its functions or to exhibit pathologies (Troncale, 2006). By understanding the organization of a system we can explore the probability or improbability of certain behaviors; not just as a result of predictable development but also resulting from emergence of new possibilities and new systems from new contextual relations. Focused application of the framework as an analytical approach can help reveal how qualitative properties of a system act to guide or direct dynamics and how dynamics contribute to higher system qualities.

For example, to some degree the framework is compatible with current trends in physics toward "model-dependent reality" (Hawking & Mlodinow, 2010), except for the "shut up and calculate" ethic (Mermin, 1989, p. 9) that tends to exclude realistic models. This trend also appears in dialectical constructivism in biology (Levins & Lewontin, 1985), and policy analysis (Morçöl, 2002; Patton, Sawicki, & Clark, 2015). Dialectical methods tend to be alternatives to classical views in physical science and ideas like sociobiological or genetic determinism (Peters, 2014; Wilson, 2000). This dichotomy is roughly the difference between strong pragmatism (denying more than instrumental "usefulness" of ideas) and strong realism (belief in positive confirmation); or put in the grossest generalization, one sees unity to be an illusion and the other sees plurality to be the illusion (Schrödinger & Hastings, 1964). Similar dichotomies appear also in opposing views of free will, and the question of whether nature itself can be said to have the quality of mind. We need a way to bridge these gaps (Venkatesh et al., 2013; Wiek, Farioli, Fukushi, & Yarime, 2012) that seems suitable for "new" or "post-normal" science (Funtowicz & Ravetz, 1993; R. Rosen, 1999; Schrödinger, 2012).

In practice, it may be that both views tend to incorporate aspects of each other (Martin, 2007). For example the idea that novelty implies a constructive purpose was famously challenged in an analogy to architectural "spandrels" that appear inadvertently between supports in cathedrals and provide accidental space for art (Gould & Lewontin, 1979). The point was that emergent opportunity can be a consequence of necessities. The advent of mixed methods research (Halcomb & Hickman, 2015; Johnson & Onwuegbuzie, 2004; Johnson, Onwuegbuzie, & Turner, 2007) is one attempt to reconcile these differences, as perhaps is critical realism (Zachariadis, Scott, & Barrett, 2013), social practice theory (Reckwitz, 2002), process philosophy (Gare, 2011; Ulanowicz & Kauffman, 2009), and a number of other paradigms that have emerged with the aim of providing a post-positivist integration (as opposed to a complete substitution) for comprehending systems.

The problem has been that unqualified realism can become dogmatic, but its strength is in its method of testing for what may be considered the best model of nature. We can accept that a single best model may not be found, and yet, it still does not follow that all models are thus theoretically equal. Similarly, pragmatism can suffer from testing in terms of human expectations alone, whereas it does not need to exclude the idea that nature can establish its own contextual realities and produce mechanisms that positivistic methods reveal. The fact that these two approaches each seem to produce valid results further emphasizes that construction is a natural process; that after all, humans came out of nature, not into it; so our own internal models must in some sense *know* nature.

As a result of these assumptions, natural scientists might miss the point that natural encoding occurs contextually; that is, every measurable event must have a formal domain that specifies the organization of measurements—how they are entailed in a metrical space. Dialectical practitioners may miss the point that social construction would be worthless without natural encoding; in other words, human concepts cannot be useful for interacting with nature if they are not, in some way, derived from it. In defense of both views, the realistic search for natural models has been the most effective way to test our assumptions about nature, but only given that it is combined with the constructive freedom to explore new models and new foundations.

Modeling Relations

The holon framework presented in Fig. 2.1 can be directly related to Rosen's concept of a "modeling relation." That modeling relation, shown in Fig. 2.4, is the vehicle that takes us out of our normal way of thinking about nature and science.

The modeling relation is between a "natural system" and a "formal system" that involves encoding and decoding the formal system in a way that agrees with the natural system (R. Rosen, 1990, 1991).

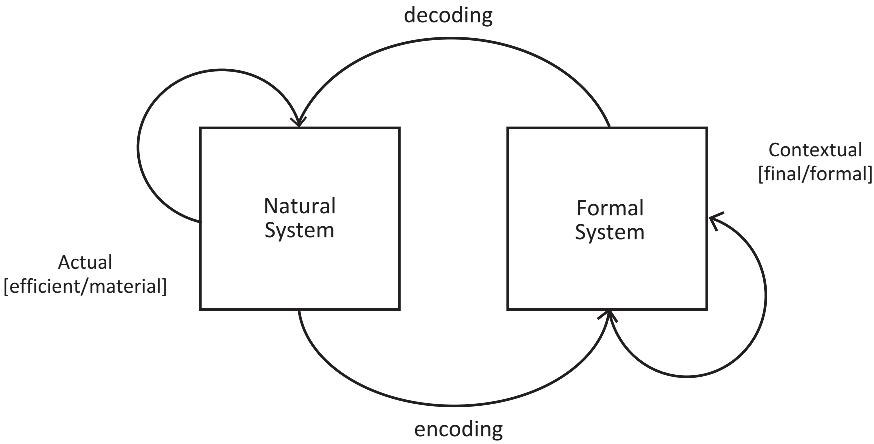


Fig. 2.4 The modeling relation

Rosen also demonstrated that both sides of the relation could be natural systems (modeling each other), or they could both be formal systems (as with models within mathematics itself). The curious fact, however, is that the encoding and decoding operations are *not part of either system*; they are, essentially, what is done by the researcher. If we remain with that view, we can think of both the model and the natural system as containing analogous efficient causes, and the researcher is the one who compares them (more or less by analogy). But then who or what is encoding a natural model, which Rosen demonstrated is characteristic of all life? To address this question, we need to consider the possibility of modeling a complex or living system and the possibility of using a complex model to do that. As shown in Fig. 2.5, a Nested Modeling Relation, it is a modeling relation between modeling relations, potentially without end. Rosen was able to state another property of complexity on this basis in that a complex system has no "largest model." If a system does have a largest model (one that explains everything), then it is a mechanism (as in classical science).

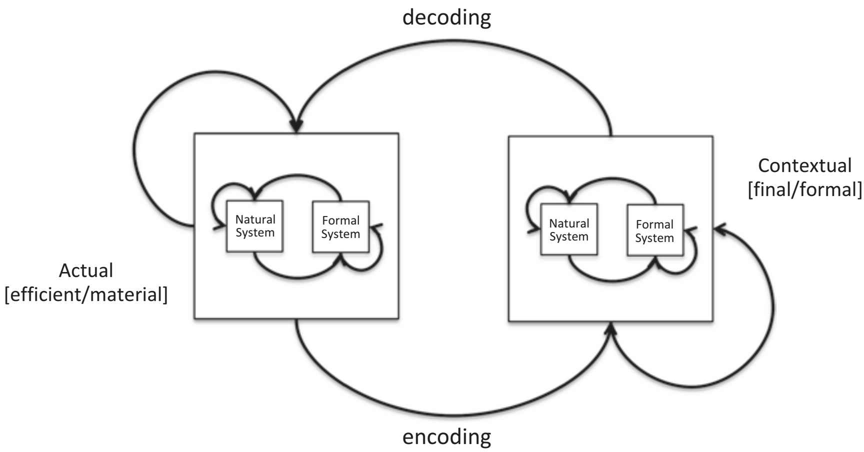


Fig. 2.5 Nested modeling relation

This diagram suggests a possible solution to the problem because it has embedded the coding relations of one level into the modeling relation of another. Unfortunately, it comes at the cost of adding complex relations because, as soon as there is an internal model generated by the system being studied, there is a system-dependency (impredicativity). We lose the ability of modeling relations to commute precisely, which means that the path of entailments and coding relations through the model gives the same results as a study of the system itself. This kind of infinite regress is a problem for science, because it compounds impredicativities rather than analyzing them. This regress prompts the next question, “Is there a way to preserve the uniqueness of a system–model relation while still considering internal models?” Indeed there is, but it comes at another cost.

Modeling Relations: Contextual Entailment

We must consider a differently entailed contextual domain of reality. Instead of considering the relation that exists between material systems (model and modeled), we need to consider the relation that exists between the material system and the coding processes themselves, where the translation between efficient categories takes place. By encoding and decoding we mean a translation from one side to the other, preserving the entailment structure of each (meaning to preserve the causal organization of each system as they are compared). If that translation is between two efficient systems, as might be supposed, then the translation must involve an intermediate inversion—an inverse entailment, which is what we call a *contextual entailment*.

We can now consider a much more meaningful modeling relation that underlies the obvious analogy between the behavior of a model and the behavior of what it models. It is possible to consider the modeling context as causal in its own right; that which produces the functions that generate and/or operate the system. For the sake of distinguishing them, this might be called the *fundamental modeling relation* as opposed to a *realized modeling relation, which is more like an analogy*. The fundamental relation is between a system and its laws, as is the relational holon.

This result is an interpretation of the modeling relation diagram by which it becomes a very powerful analytical tool. Figures 2.4 and 2.5 remain the same but we now understand the right side of each relation to be an inverse entailment—the inference of a function itself, rather than a surrogate material system built from such inferences.

The question arises as to what can be done with an inverse entailment map. To date, it has been overlooked as being “inaccessible,” having to do with the inferential abilities normally associated with consciousness (Merlin, 2001). To some degree it is already referenced in the category theory logic, but not commonly examined as proposed here. Efficient entailments result in measurable states, but inverse efficient entailments—final entailments—result in functions.

But if encodings and decodings preserve homomorphic entailment structures (as they are supposed to), then there must be logic which can be applied to the contextual entailments to achieve that. This case is clear with regard to the fact, mentioned earlier, that mathematics is replete with models of mathematics. In fact, contextual logic can tell us a great deal about the qualities and organizational aspects of a system. Far from being inaccessible, contextual analysis opens up new possibilities for complex system analysis.

It is clear from category theory that the encoding and decoding relations between categories[8] are not the same as entailments (causal maps) within categories. They convey and preserve information about the entailment rules ("mathematical structure" as defined in category theory) in each category and translating that information into the other category. Perhaps it is not too difficult to see that the logic of what occurs in the world must be attributed to the contextual category. This is where we get boundary conditions on natural phenomena (the supposed "natural laws" which specify what *can* happen and *how*). The problem is, these laws are neither known, except by experiment, nor are the boundary conditions known on the laws. All that information is part of the formal nature of a contextual entailment, including discoveries like quantum uncertainty or (if it is true) vacuum energy.

Presently, this type of information is considered a "black box" that few want to look into except to find mechanistic formalisms. But the four-cause holon cycle indicates that what is in that box is itself related to its complementary category—the world of phenomena. In that case, what appears to be unknowable, sometimes referred to as "law without law" (Wheeler, 1981, p. 182), may have some primitive logic associated with the inverse (final) entailment mapping and its relation to actual phenomena. Exploring that logic will reveal organizational aspects about whatever system is being studied that could not be seen before. In fact, science has already peeked into the box in the case of quantum probability, relativity, niche models, and affordances.

Modeling Relations: Actualized Entailment

Now, it is important to consider the different, complementary nature of these two categories. The entailments we describe on the actualized side are about phenomena in a "local" world with coordinates where measurement is possible. It lends itself to efficient (dynamical) description. The entailments on the contextual side are about models, which in a meaningful sense are about potentials and possibilities for existence, which, with regard to the world we define in terms of space and time, is *nonlocal*. It becomes generative or behavioral with respect to actualizations of its models in material systems.

The descriptive methods for actual versus contextual categories are different. Efficient entailments occur in a world of discrete events and objects (which has specific formal conditions), whereas final entailments are in a nonexclusive space that does not not have locality or temporality directly. A simple optimum in temperature, for example, has no locality in space and time as such, except through

[8] Technically, in category theory, these are "functor" relations, explained in Chapter 4.

actual temperature distribution. Each of these specifications thus varies independently and according to different rules. Thus, indeed, we are describing a complementarity. As Alfred Korzybski famously wrote, "The map is not the territory" (Korzybski, 1933, p. 750).

There are several examples in science. In quantum theory, it is necessary to consider the nonlocal *quantum vacuum*, which has tremendous potential energy. The same need appears in cosmology in the *cosmic void* or *dark energy*, which is an unmeasurable existence needed to account for the expansion. In human and social systems there is the question of goals, plans, designs, and many aspects of a conscious mind. These concepts are not integrated as each postulates nonlocal contextual domains. Throughout the history of science and humanity, philosophers have considered the idea of such a domain in terms of *aether* or *plenum* (Greek and Latin terms for the substance of space itself), Kant's *noumenon* (as potential for phenomenon[9]), and even various kinds of "fifth-essence" unity. In Indian Vedic philosophy it is known as *akasa*, which is like a natural memory of phenomena associated with an informational existence, sometimes called "nonexistence" that together with "existence" makes a whole.

Such considerations were excluded from early Western science in order to focus on mechanisms, holding the contextual side of all relations (in nature or in science) constant. Thus, they were really just overlooking variation of final and formal cause, whereas the existence of those domains had to be acknowledged, albeit prior to science.

Hence, the formal domain itself is entirely present in science as natural law reflected in our formalisms, implicating a corresponding order in nature. Today, there is tacit agreement that there must be a model-like complement of the phenomenal domain that is responsible for complexity (Hawking & Mlodinow, 2010; Henry, 2005). We do not want to get lost in the immense implications and history of this view, but it is important for the reader to realize that the framework is not a simple heuristic. It is appropriate in some cases but not others. If the framework is valid, it tells us something fundamental about nature, which is why it tells us something general about systems.

Holon and Modeling Relation as Semantic Relations

We have learned that the coding relations in the holon and modeling relation must be described as information relations. They translate between different kinds of entailment. For example, a scale model of a house might be similarly entailed as the eventual house. But the one cannot become the other, except by informing its construction through its meaning. So, they are semantic relations: encoding into an

[9] There have been various views of noumenon, but even Kant's idea dismisses it by simultaneously overstating its reality ("the thing itself") and then declaring it unknowable. Here it is nothing more than contextual potential for existence of phenomena, researchable through inference.

inferential model (context) and decoding into measurable phenomena. We can abandon the idea that they are in some sense “unnatural.”

By this very elegant modeling relation, Rosen raised the question of information *in* nature, and implicitly, *mind* in nature (Penrose, 1994; R. Rosen, 1993; Wigner, 1981). This relation is further addressed in Chapter 4 and considers modeling approaches in science.

The two domains and four causes defined by a modeling relation are only analytically separate—that is, a system should be thought of as having all aspects, even if only one is apparent at a given time, place, or scale. So, we can use the modeling relation in multiple ways. It can represent one system that has these complementary aspects, or it can represent a relation between complementary aspects of two systems. Thus, it can define a systemic relation or a relation between systems and we can use it to look at relational closure as appropriate. This solution creates an infinitely holographic order (scalable and self-similar) comprising modeling relations *all the way up and all the way down* (see Fig. 2.5).

Ubiquitous Appearance of Four-Cause Frameworks

Where uncertainty or natural indeterminism (as one assumes) seems to rule, the mechanistic approach of the physical sciences does not seem to do well. It is clearly for a special kind of system that does not include the subjective influences normally attributed to agent-like (as opposed to law-like) complex processes. It also leaves out the living and human worlds about which we are ultimately concerned as individuals and as a society. Nevertheless, the machine metaphor is still routinely applied to living systems. Consequently, each discipline has had to invent its own framework for considering contextual causation. Following are examples indicative of their ubiquity and how the holon framework can be used to integrate them.

In current science and management practice, the four-quadrant framework can be seen in various forms:

- Environmental assessment (Kristensen, 2004),
- Integral ecology (Esbjorn-Hargens & Zimmerman, 2009),
- Adaptive assessment and management (Holling, 1978; Olsson, Folke, & Berkes, 2004),
- Sustainability science (de Vries, 2013),
- Learning organization (Örtenblad, 2004; Senge, 2006),
- Autopoiesis (Maturana & Varela, 1980),
- Vedic ecology (Kineman, 2005; Prime, 2002),
- Evolutionary learning (Walker, Cisneros, & Davies, 2012),
- Niche construction (Kylafis & Loreau, 2011; Odling-Smee, Laland, & Feldman, 2003),
- Time and cosmology (Masreliez, 2012; Smolin, 2014; Unger & Smolin, 2014),
- Holistic ontology (Checkland, 1988; Edwards, 2005; Koestler, 1970; Lowe, 2006),
- The mind-brain problem (R. Rosen, 1993),
- Second order (or new) cybernetics (von Foerster, 2003), and more.

Consider this example from environmental science: The “Drivers-Pressures-State-Impact-Responses” (DPSIR) framework (Fig. 2.6), which defines a cycle of social drivers and natural processes that are part of an environmental assessment (Kristensen, 2004). DPSIR is used extensively in environmental assessment and management. It was also adopted as official policy by the European Union (Atkins, Burdon, Elliott, & Gregory, 2011; Bell, 2012; Ness, Anderberg, & Olsson, 2010; Tscherning, Helming, Krippner, Sieber, & Gomez y Paloma, 2012).

The DPSIR framework is easily interpreted in terms of PAR Holon cycles. The usual representation, as shown in Fig. 2.6, is obviously confused about what to do with Response, how it is actually supposed to work except that it needs to interact with all the other elements. But response must also be organized in a natural way.

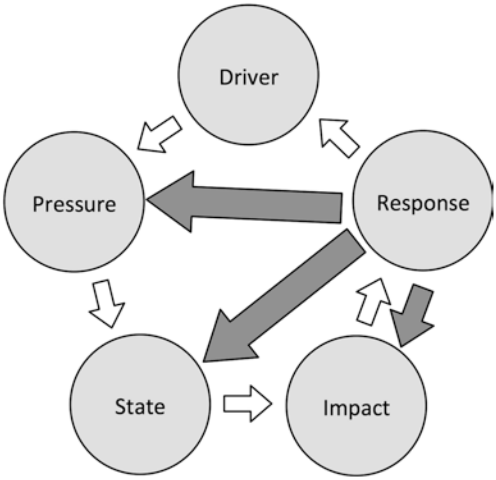


Fig. 2.6 DPSIR framework

When we realize that Response is another holon cycle, initiated when impacts are assessed (as tacitly implied by the small reverse arrow in Bell’s diagram), the diagram can be redrawn in a way that is much more understandable and much more informative as a second order complex closure, shown as DSPI/R in Fig. 2.7, each cycle responding to the other with closure in the Impact/Response quadrants.[10] In other words, they are *closed to final cause*. In a sense, we can imagine that as a closure with each system’s future. The assessed impact on the system’s future is taken into a management context to design a plan to alter that trajectory. The holon view also emphasizes that the process should not stop with one Response, which itself can have unexpected impacts. The ecosystem changes introduced by management action thus close with the ecosystem context, from which there is another round resulting in impact from the management changes. Closure means the two

[10] They are not fully “closed” because besides this interaction each also has its own cycle that continues independently (management systems do have inertia!) and each can be influenced by other systems.

cycles exist together as a complex adaptive cycle as recommended in Holling's (1978) book, *Adaptive Assessment and Management*, but rarely implemented.

The DPSI/R example also shows how to use the worksheets (see Section "Appendix: Worksheets") for basic holon analysis. There are many subtleties of using this framework. For example, the Response cycle essentially replaces the Impact arrow in the Impact cycle; thus implying assessment of the impact and intervention in the Ecosystem contexts. The result is equivalent, but this double loop diagram is explicit about both cycles. Of course, it is arbitrary which cycle is drawn on the inside or outside, except to suggest a general convention of placing the genetic identity inside the behavioral identity.

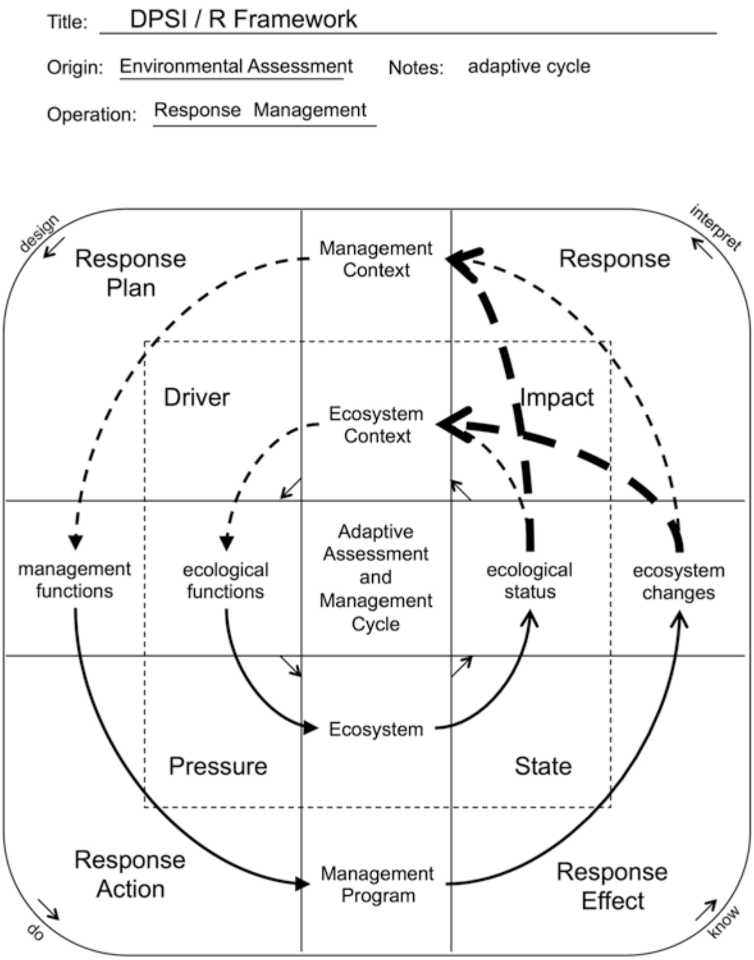


Fig. 2.7 DPSI/R holon worksheet

It is worth discussing this case a little more generically as a model of complex relations. Clearly, in this case, management models may not exist in the same formal domain as natural processes, which is the criterion stated earlier for complexity. Typically, this basic case of complexity will identify two very different kinds of systems, one that is about existence and one that is about behavior. Those two contexts are present for everything that exists and interacts; their formal models are generally not miscible (as with evolution and ecology, waves and particles). For an organic system, these two cycles can represent genotype and phenotype, in Chinese philosophy, also known as Yin and Yang.

Even in engineered systems it is clear that the goal of engineering design is to separate these two cycles as much as possible; one being the design/production cycle—the origin of the system, and the other being the operation/use cycle—the behavior of the system. In organisms, these run simultaneously; we are redesigning ourselves as we live. But that is the opposite of what we want machines to do, at least until we can guide their redesign. Our mechanistic view of nature in modern science has implied the same thing—separating origin (the big bang and absolute substance) from operation (dynamical laws of conservative reconfiguration). While that separation does appear in nature of its own accord, we are now confounded by the many cases where origin and behavior remain in relation—the case where complex relations (between original and operational causes) have been preserved by causal boundaries (which isolate phenomena from highly interactive domains).

As another example, Peter Senge's "Fifth Discipline" (or learning organization) defines a learning cycle in management that also relates these four causes and indicates a fifth level unity (Garratt, 1999; Örtenblad, 2004; Senge, 2006, 2014). The basic learning organization cycle can be easily shown in the PAR framework (Fig. 2.8). As such the learning organization attempts to be whole by defining each one of the quadrants and their fifth level unity as an identity cycle. But to the extent that it achieves a whole organization like a living organism, it will then have the same phenotype and genotype interactons with its environment—the world of competitors, customers, resources, and so forth. The internal organizational stability (its genetic identity) is thus necessary, but not sufficient without further analysis of the external relations (its behavioral identity).

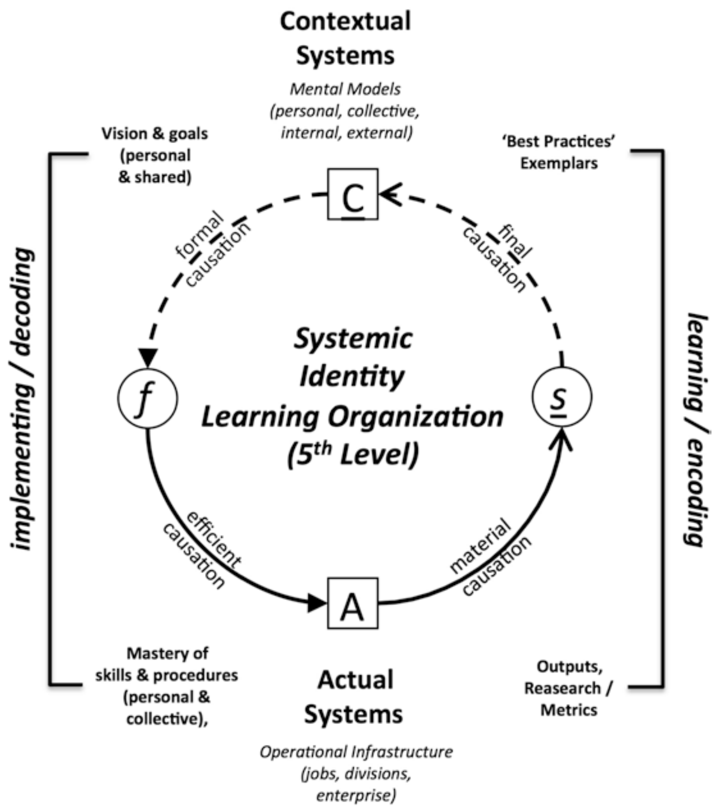


Fig. 2.8 Learning organization (as a holon)

For our purposes, it is unnecessary to review the many instances of similar four-cause frameworks in various disciplines; the point being that we have not connected them to develop a general theory. There have been some attempts, for example an almost lost theory of "quaternios" presented by Carl Jung (Jung, 2014; Stein, 2012), in which he proposed a very similar holon relation to explain "the archetype of the Self." Although set in a mystical theological context deriving from Kabbalah, alchemy, and Gnosticism, this work was meant to suggest a general science of wholeness and consciousness. The basic intuition corresponds with our framework. However, its ties with many interpretive schemas seem to confuse its general meaning. The interpretation Jung (2014) cites from Athanasius Kircher seems to correspond best. A more recent holon schema by Kenneth Wilber (Wilber, 2007) shows similar deep cultural and psychological insight. The best correspondence, however, still seems to be with more ancient concepts in the Vedas and Upanishads of India, from which many of these ideas may have descended with various modifications.

Ways of Using the PAR Holon Framework

Figure 2.9 shows the various ways that the PAR Holon Framework can be used by combining holons. The most primitive diagram is a system identity (Fig. 2.9, diagram A), which is a first order holon (meaning it contains one holon). This is also the basic framework view presented in Fig. 2.3, which gives the quadrant labels. Here we look at the four nodes of the diagram as: Context (C), *function (f)*, Actualization (A), and *structure (s)*, the system elements that are causally entailed by the four quadrant causalities discussed earlier. These are the ontological elements (C, A) and epistemological elements (*f, s*) of the system. The system identity, can also be represented by a label at the center of the holon (e.g., "house," "Lake Erie," "Fred," etc.), recognizing that a single loop is an analytical idealization and in reality it has other relations.

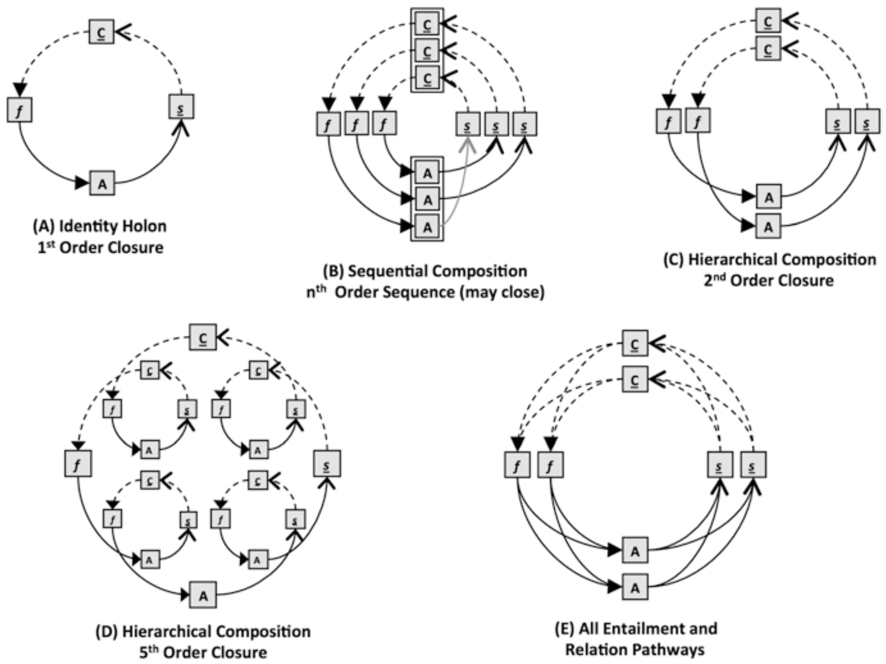


Fig. 2.9 Holon compositions

Holons can interact with other system holons in any of the four quadrants (Fig. 2.9, Diagram E), although the C-*f*-A-*s* order is always preserved. This system of analysis presumes, or defines, that order to be universal. If the order is not preserved the causal relations no longer have meaning, so it is as much a fact of the analytical system as it is a statement (or hypothesis) about nature's organization. It is generally helpful to keep track of the identity loops as well, and one may choose a common letter identifier for all the nodes in a given system (in which case the letter format and highlighting can be used to keep track of its role). Contextual entailments are shown as a dashed line and actualized entailments are shown with a solid line. Formal and Efficient cause (decoding) have solid headed arrows, Material and Final Cause (encoding) have open headed arrows. The PAR Holon quadrant labels (causes) belong to the arrows entailing these elements.

With these simple conventions very intricate system diagrams can be drawn without losing track of sub-systems, identity relations, and interactive relations. It may be useful to think of these nodes as the *nouns* and the quadrant causes described earlier as the *verbs* in the holon syntax. The holon is therefore a language repeating a fundamental statement of systems: *A function applied to a behavioral system produces states that in turn alter the contextual boundaries of a system to establish new functions*. Everything about systems is assumed to be a more specific version of that story.

The typical spiral PAR cycle (shown in Fig. 2.2) corresponds with Fig. 2.9, Diagram B, which is a sequential composition. This kind of holon composition also corresponds to temporal sequences or processes in physical nature. One way to interpret the diagram is that when a given state is produced from interactions or observations it is part of the contextual topology as well. In a classical context, the effect is to produce the next temporal event in a law-like manner. In a complex context there could be uncertainty and even nonlinear effects. The sequence appears to us as a state change, but in this framework it is a discrete change, like a movie frame. The systemic implications seem to correspond with quantum theory in the sense that events do not really *move* between observations, but are essentially recreated from the context in the newly observed location. If this becomes our accepted view of reality, it is clear that contextual causes cannot be eliminated except in approximations.

The spiral diagram can remain open, or it can at some point close back onto the original condition. For example, a planning series might eventually come back to old models, or in natural science, a spacecraft that travels far enough might return to its origin due to the curvature of space–time. Sequential maps more commonly take a snapshot out of a larger process; a quite legitimate analytical thing to do if the sequence represents a phenomenon of interest; but in that case it is a fractional view. Most of modern science stays within the fractional view.

Figure 2.9, Diagram C represents the case of a second order system closure. This is one of the most interesting cases because it is an explicit representation of complexity. That is, if we assume that the two contexts are not reducible to each other, then the system is uncertain between two rule sets (natural models). Closure means that the two systems are co-dependent (establishing each other) in some aspect. In this case, we show “efficient closure,” meaning the two systems share dynamics as, for example, in wave–particle duality or two people building a house with different ideas and plans. Such cases are complex. Closures in the other quadrants can be quite interesting as well. For example, final closure would be a case, in which two people with entirely different plans and behaviors nevertheless share each other’s vision. Material closure might describe the situation in mutualism where an animal provides nutrients for a plant that provides food for the animal, or we can find examples in domestic work relations. Formal closure is sharing a plan or boundary conditions.

It is interesting to note that such closures each require an additional holon. If two holons are closed in two ways, the original systems lose their identity and they separate into two reconfigured systems. Two holons with three closures remain closed, but the two systems are redefined and it is then the same as being closed in one quadrant. To retain system identity with more closure requires more holons. So, two closures require three holons and closure in all four quadrants requires five holons, as shown in Fig. 2.9, Diagram D. The fifth order holon is also a very interesting case because that is a complete closure at one level (i.e., not considering the unbounded possibility for sub-components). This causal organization corresponds with Rosen's "M-R System" diagram, by which he showed the minimum internal efficient closure required for a living organism or cell (R. Rosen, 1985, 1991). Note that Rosen's M-R diagram 10C.6 in the 1991 book, *Life Itself,* was misprinted, but later corrections were published in, for example, Cottam, Ranson, and Vounckx (2007), Louie (2009), and Mikulecky (2000), with various commentaries. As such, it represents the causal organization of a whole system, and if we assume it has M-R functions, it thus identifies life. It is arguably a good model for explaining diversity of causal types of life, healthy institutions and corporations, and system sustainability for which measures of health, integrity, resilience, and other systemic properties of a whole can possibly be developed.

Concluding Remarks

Readers may find the blank worksheets (see Section "Appendix: Worksheets") useful for thinking about a relational analysis. A first step in any analysis would be to list the four causal aspects of the system of interest, and to consider if these are about system behavior or system existence. They can be written as separate cycles with various forms of closure. For any given system, one may fill in related cycles (using the worksheets) following any of the configurations in Fig. 2.9, indicating with arrows where closures exist. Each holon framework diagram has eight elements, four of which are described as causes, two that define the system in terms of its ontological categories, and two that define it in terms of its epistemological codings. Thus each category comprises two adjacent quadrants. The categories are paired in the system's ontology (contextual potential and actual phenomena) and its epistemology (decoded functions and encoded exemplars). The origin of the system is thus implicit in its identity categories, whereas the causal quadrants are used to describe how it works or, more explicitly, analyze the causes of its existence. These other forms of analysis will be discussed in Chapter 4.

In applying the framework one quickly discovers that it is often not clear which aspect of a system or study belongs in which quadrant or if some aspect under consideration should be represented as one of the nodes. What will happen is that, as each quadrant or node label is decided, it will become clearer what the others should be to form a single loop relation—a system that can be identified through the study. The process is actually helping discovery of the true identity of the imagined system, which may have been only vaguely known at the outset, somewhat like the game of "Twenty Questions" (although this one has eight). Further, as different sub-systems are defined and the relations between them are worked out, each related system becomes better defined by those relations. Eventually, a picture emerges that is self-consistent and describes the system of interest. A great deal can be learned in this process of definition, such as missing elements, redundancies (that may be stabilizing overall), leverage points, root and hidden causes, attractor patterns, alternative system configurations, and so forth.

The archetypal quality of the quadrants is invariant, which is why it can be applied generally. The invariant nature of the causes is preserved in their cyclical relations to one another. By following the rules of entailment discussed here and in Chapter 4, these diagrams can be very diagnostic. What makes this framework most valuable is its mathematical foundation. Being holistic and infinitely holarchical, the framework can help analyze systems in terms of whole system components and it can also be used in fractional modes of analysis including reduction to classical mechanisms or unactualized subjectivities.

A very simple exercise to become familiar with this approach is to take a typical concept map of a system, in which the arrows and boxes rarely conform to any rigorous types, and simply apply the four causal labels to the arrows and the four category labels to the boxes. Reorganizing into quasi-holons will reveal missing pieces of each implicit identity or redundant or ambiguous components. The idea is to converge on a unique system identity leaving other possibly important aspects of the study in other holons that will later be linked in more appropriate ways. The result is to impose a natural order on the researcher's view and analysis of the subject system.

In order to create a new model, the following questions can be used as prompts:

Questions for labeling the four quadrants (the causalities in the holon diagram and worksheet):

- What is the observable/measureable result or condition of the system being described? (material aspect)
- What actions, agents, or dynamics produce that observable result? (efficient aspect)
- What guides, shapes, or regulates the dynamics? (formal aspect)
- What prior idea, meaning, or exemplar does the guidance follow from? (final aspect)

Here are some questions for labeling the four parts of the system identity (the ontological axis connecting context and action, and the epistemological axis connecting function and structure).

- What *actual system* (system that acts in the world) is indicated by questions 1 & 2 above?
- What *functions* (performances) are implied by questions 2 & 3?
- What *contextual system* (systemic model) is indicated by questions 3 & 4?
- What *structures* (measurable and meaningful patterns) are represented by questions 1 & 4?

The real strength of going to a relational analysis is to discover underlying causes of complexity and patterns of organization. Those patterns, in turn, can then be quantified as to their relative presence or strengths, perhaps by inserting specific models of each type from new or previous empirical research. Where complexity is not significant as compared with predictable behavior, a mechanistic model may do. Where one does not need much specificity about contextual causes, a probabilistic model may do. For more detailed analysis, each quadrant may be further decomposed into sub-holons (or related to describe more inclusive systems).

Each quadrant can thus be the container for an appropriate method written in any terms that work sufficiently for the purpose. The caveat, of course, is not to forget that a potentially limiting or explosive assumption may have been made by doing that. But still the relational framework will help keep track of those instances. Increasingly, complex problems require relational analysis to find causes at greater and greater intricacy depth and increasing possibilities for answers.

The holographic organization means we have the tools to analyze whole systems in terms of whole systems. It also allows us to plug in any useful description into a relational analysis if we make the assumption that deeper analysis is not needed. For this reason, the approach is completely compatible with current analytical methods—it simply adds natural organization to reveal constraints and opportunities. This may seem to contradict the claim that the relational analysis is a fundamental reality, but the point is that using other models formalized heuristically is essentially an approximation to that quadrant's role. The key is not to apply a model that crosses the boundary between contextual and actual system domains—that must be done by coupling models to avoid reduction. Chapter 4 explains details of models as entailment relations, which exist in both contextual and actual system domains.

As a final example, Fig. 2.10 applies the framework to describe the organization of the chapters in this book.

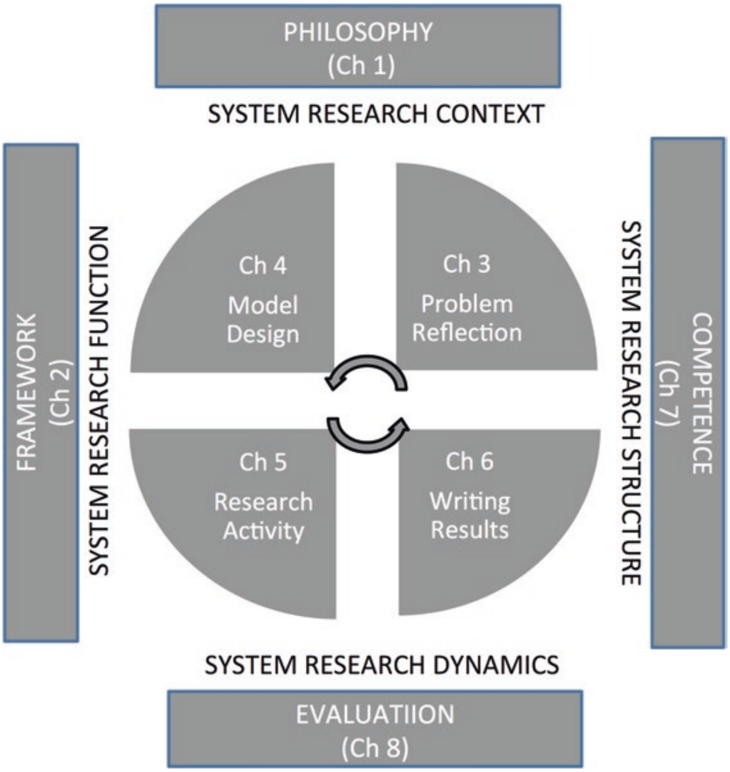


Fig. 2.10 PAR Holon organization of the book chapters

In Chapter 3, Problem Structuring and Research Design, the implications of the framework chosen for systems research are realized. The framework serves as the basis for further analysis of the system, its properties, behaviors, and pathologies. Using a disciplined approach will help clarify the dynamics of the subject system, so a comprehensive description and robust model (Chapter 4) can be developed. Once researchers have a clear understanding of a subject system and the problem to be addressed, even if that "problem" is a theoretical development, Chapter 3 addresses research design to guide researchers in making choices suitable to the system as envisioned.

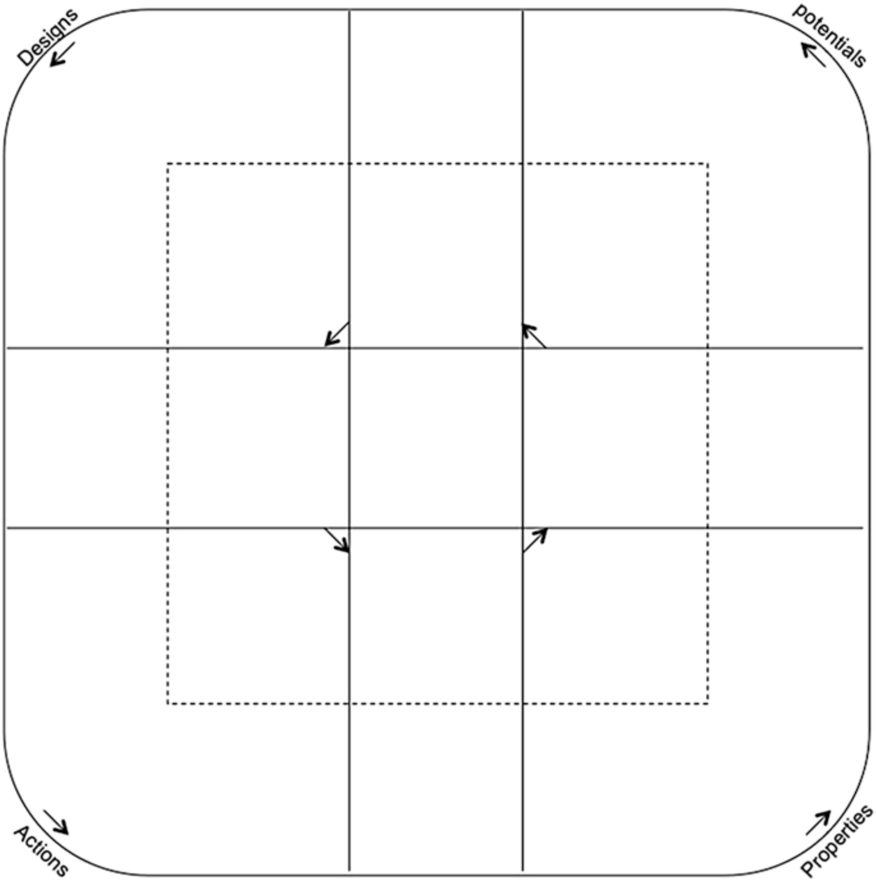
Appendix: Worksheets

1st/2nd Order (open) Holon Worksheet

Combined System: ______________________________

Internal System: ____________________ Notes:

External System: ____________________

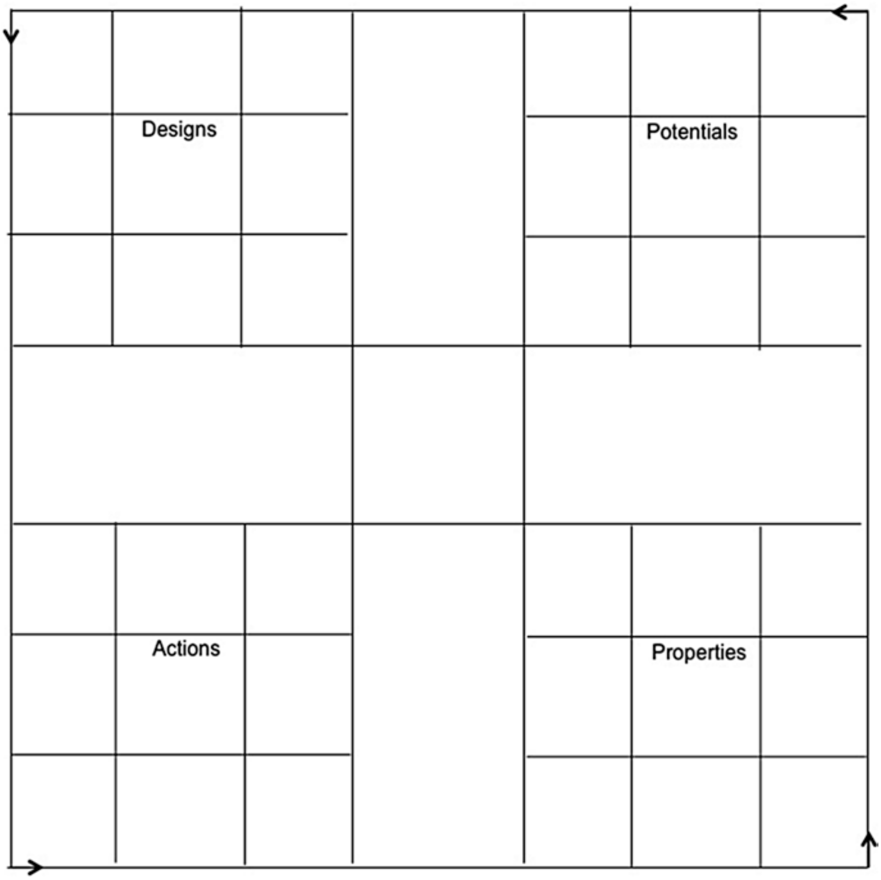


5th Order (closed) Holon Worksheet

This Holon: ______________________________

Parent Holon: ______________ Notes:

Quadrant Link: ______________



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