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Ideas and Graphs

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IDEAS and GRAPHS

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Contents

Abstract: A graph can specify the skeletal structure of an idea, onto which meaning can be added by interpreting the structure. This paper considers graphs consisting of four nodes, and suggests meanings that can be associated with several different directed and undirected graphs. Drawing on Bennett's "systematics," specifically on the Tetrad that systematics offers as a model of 'activity,' the analysis here formalizes and augments the systematics account and shows that the Tetrad is a versatile model of problem-solving, regulation and control, and other processes.

Key words: graphs, John G Bennett, systematics, Anthony Blake, number symbolism, tetrad, tetradic structures, Charles Sanders Peirce, Talcott Parsons, action

1. Introduction

> "God made the integers; all else is the work of man - Kronecker (Bell 1986)

Graphs can be associated with ideas, different graphs with different ideas. I include graphs in which links between nodes are directed or undirected. I focus in this paper on graphs involving four nodes, and show that 4-node graphs can represent the skeletal structures of different complex ideas. Of the $2^6 = 64$ possible undirected graphs and $3^6 = 729$ possible directed graphs, only a small number are discussed here, but these should be sufficient to show that different ideas can be associated with different graphs. I will not be discussing hypergraphs, in which links can connect more than two nodes.

This study is based on the "systematics" of John G. Bennett (1956, 1961, 1966, 1993) further developed by Anthony Blake (1997, 1998, 1999) and others; more particularly on the concept in systematics of the Tetrad. Bennett (1897-1974) is a little-known British scientist, philosopher, and religious teacher, whose wide-ranging interests and system-building efforts bears comparison with Whitehead. As a modern version of number

symbolism, a traditional mode of thought occurring widely in many cultures of both West and East, systematics has strong and explicit affinities with systems theory (Bennett 1963, 1970). Bennett refers to the categories of systematics, namely the Monad, the Dyad, etc., as "systems," and the structures of these systems to which meanings are assigned are graphs, namely nodes connected by links, or, in the terminology of systems theory, elements connected by relations.

While systematics was developed outside the context of contemporary philosophy of science, its Monad, Dyad, and Triad resemble Charles Sanders Peirce's (1868) notions of Firstness, Secondness, and Thirdness, so this study could be viewed as a proposal to add a category of Fourthness to Peirce's framework. The progression for Bennett from the Monad to the Dyad and Triad and Tetrad (and further – Bennett goes up to twelve, the Duodecad), or the progression for Peirce from Firstness to Secondness to Thirdness (Peirce stops at three), is a complex subject in its own right; generative relationships among the categories are not addressed in this paper. The focus of the paper is only on one category: the Tetrad. This category by itself, however, can take on multiple graph structures. These different structures can be associated with different meanings, and these associations illuminate the elusive relationship between syntax and semantics.

2. The Tetrad of systematics; applications

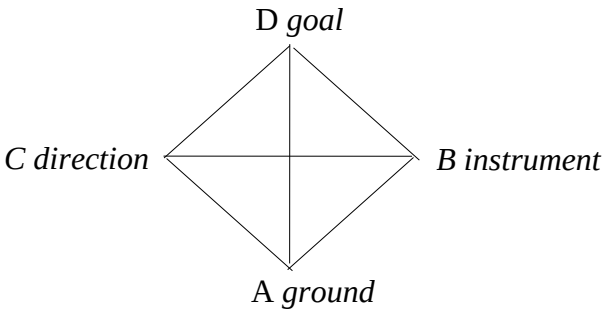
2.1 System and its terms (nodes)

Systematics is a philosophical system that is still in development, and its literature offers varying formulations of the tetrad which differ in details. A common idea is recognizable in most of these descriptions, but it is not necessary to insist upon a *single* interpretation for the tetradic system attribute and for the four terms of the system. An ensemble of alternative meanings for this attribute, as long as they are related and as long as there are not too many of them is plausible and not less interesting.

Figure 1 is a close approximation[1] to Bennett's representation of the Tetrad. The four elements ("terms") in this system are *ground*, *instrument*, *direction*, and *goal*, labeled A, B, C, and D, respectively. The six undirected pairwise links are called "interplays."

Figure 1 Tetrad (Bennett 1966)

Four-term System: TETRAD
Systemic Attribute: ACTIVITY
Term Designation: SOURCE
Term Characters:
MOTIVATIONAL: *ground* (actual)
goal (ideal)
OPERATIONAL *direction* (theoretical)
instrument (practical)
1st Order Connectivities: INTERPLAYS (The six interplays are lines in the diagram.)



[1] Bennett puts *instrument* on the left and *direction* on the right. The figure reverses these because top→bottom and left→right directions are parallel in English, and since, as discussed below, *goal→ground* more closely parallels *direction→instrument* than *instrument→ direction*.

The links (interplays) between elements are labelled as AB, AC, AD, BC, BD, and CD. When links are directed, labels are underlined, e.g., AB means A→B and BA means A←B. AB and BA, when not underlined, are equivalent. A graph consisting of multiple dyadic links has these links separated by colons (":"). Thus, AB:BC:CD means a path either from A to D or from D to A or one of six other possible meanings, but AB:BC:CD means the specific directed graph A→B→C→D.

"Activity," the system attribute for the Tetrad, means activity that is purposive, not random. Although such "activity" might refer to the behavior of any organism, and might even be applied to processes that do not involve living systems, Bennett presents the Tetrad, as well as the other categories of systematics, primarily in the context of human action. This is suggested by the basic distinction made between motivational and operational terms and by the correlation of the terms of the Tetrad with Aristotle's Four Causes (Bennett 1966), shown in **Table 1** (with an alternative possible correlation).

Table 1 Two correlations of the Tetrad with Aristotelian causes

		Bennett	(alternative)
goal	Ideal	Formal	Final
direction	Theoretical	Final	Formal
instrument	Practical	Efficient	Efficient
ground	Actual	Material	Material

2.2 Interplays and partitions

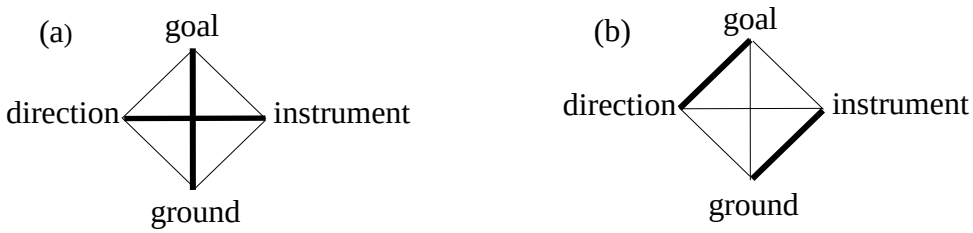
The overall system attribute and the four individual terms bracket the description of the system. Between these limits, there are many structures that involve undirected or directed relations between pairs or – if one allows also hypergraphs – triplets of terms. Of these structures Bennett speaks only of undirected pairwise relations ("interplays"). The most important interplays are the vertical and horizontal axes of motivation and operation, respectively; the interplays are listed in **Table 2**.

Table 2 Interplays

ground-goal	AD	Motivation
ground-direction	AC	Governance
ground-instrument	AB	Skill
goal-direction	DC	(not given by Bennett, but suggested here: Understanding)
goal-instrument	DB	Integrity
direction-instrument	CB	Operation

As a conjunction of these two axes, the Tetrad has the graph structure AD:BC, i.e., *ground-goal* : *direction-instrument*, shown in **Figure 2**(a). There are other 2:2 partitions possible. For example, structure AB:CD, i.e., *ground-instrument : direction-goal*, shown in **Figure 2**(b), is mentioned below in the section on Talcott Parsons' theory of action.

Figure 2 Partitions, 2:2



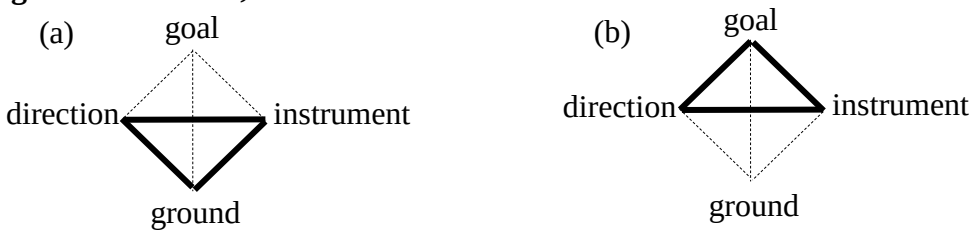
One can consider also 3:1 partitions, two of which are listed in **Table 3**. Bennett displays the first partition, *ground-instrument-direction* : *goal*, as a tetrahedron with a triangular *ground-instrument-direction* as its base and *goal* as its apex, as shown in **Figure 3**(a). . (In the figure the apex is connected to the base by dotted lines to suggest the pyramidal structure; since these structures are partitions, the apex is not actually linked to the base.) Apex and base represent a distinction between an *ideal* which may not yet exist, and the triad *ground-instrument-direction* which does exist. This triad might be considered as expanding the first term of the *ground-goal* motivation interplay: more exists than the *actual* state of affairs and this more (*direction* and *instrument*) provides the possibility for the *ground* to be transformed into the *goal*. In this first partition, *ground-instrument-direction* is a subgraph without specified links between elements and is labelled as ABC.

Table 3 Partitions, 3:1

Base	Apex	Structure	
ground-instrument-direction	goal	ABC:D	already existent vs ideal
instrument-direction-goal	ground	BCD:A	controlling vs controlled

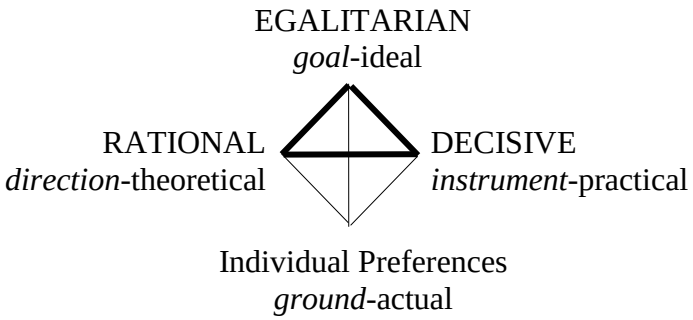
The second partition in **Table 3**, BCD:A, is useful for describing the tetrad as a model of control. This partition distinguishes between the system that is controlled (*ground*) and the three controlling terms (*goal-direction-instrument*). *Instrument* is the term that is in direct contact with *ground*; the purpose of control is to bring *ground* in conformity to *goal*; the strategy (theory) that governs the application of *instrument* to *ground* is provided by *direction*. The controlling triad and what it controls is shown in **Figure 3**(b).

Figure 3 Partitions, 3:1



To shift the application area from control to decision theory, the 3:1 partition of **Figure 3**(b) has a different character when used to display the paradox revealed by the Arrow Impossibility Theorem. Arrow (195) showed that when there are more than two alternatives, one cannot aggregate individual preferences among these alternatives in a way that is simultaneously decisive, egalitarian, and rational. Here, *ground* is the set of preferences that need to be aggregated. The upper triad reflects the three conflicting requirements for a successful aggregation.

Figure 4 Arrow impossibility theorem

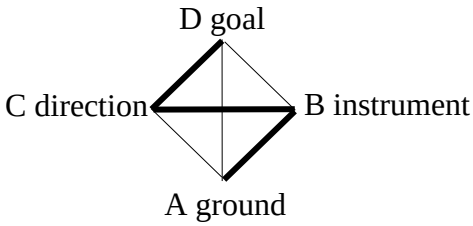


2.3 Hierarchy

Interplays are only pairwise relations, and partitions divide the system into subgraphs. Graphs that link all four elements are obviously also of interest, and the simplest of these graphs are sequences that order the elements lineally. There are 4*3*2*1 = 24 such sequences. Bennett does not explore these, but he does explore all six sequences for the Triad. He represents the terms of the Triad by numbers 1 (active), 2 (passive), and 3 (neutralizing), and gives specific interpretations to the triadic sequences 123, 132, 213, 231, 312, 321. The analysis of Tetrad sequences below proceeds similarly (for only a few sequences) and thus supplements the systematics literature on the Tetrad.

An important sequence discussed in this literature arrays the terms of the Tetrad in one dimension with *ground* and *goal* at its limits and *instrument* and *direction* at intermediate points. This is shown in **Figure 5** which is an undirected graph which can be read going up from *ground* to *goal* (AB:BC:CD) or going down from *goal* to *ground* (DC:CB:BA); the undirected graph AB:BC:CD (where the order of terms is arbitrary) can represent both directions or either one. The zig-zag path conveys an additional non-hierarchical idea: although *direction* is closer to *goal* and thus higher than *instrument* which is closer to *ground*, there is a secondary sense (in the idea of a motivational axis) in which *direction* and *instrument* are on the same level. The hierarchical sequence of **Figure 5** is actually not explicitly given by Bennett, but is implicit in his discussion of the Tetrad, and features prominently in Blake's work.

Figure 5 Hierarchy



2.3.1 Action (Parsons)

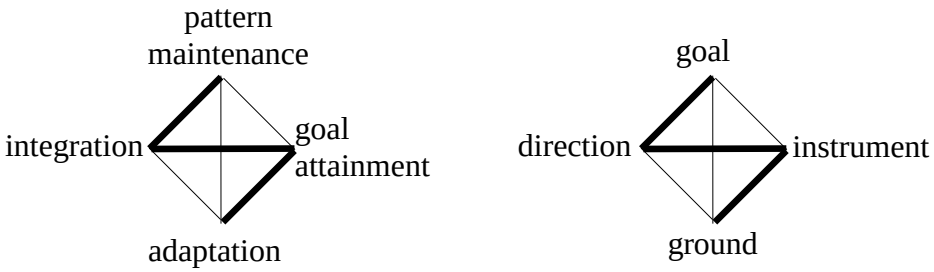
A clear example of this hierarchy is Talcott Parsons' theory of action (1966, 1971). Parsons writes: "Action consists of the structures and processes by which human beings form meaningful intentions and, more or less successfully, implement them in concrete situations." Although Bennett's idea of "activity" is broader than this notion of "action," since it might apply to behavior of other organisms and even to some non-living phenomena, most of Bennett's examples are in fact drawn from the human sphere.

The first column of **Table 4** lists the elements of action in general. The second column interprets these elements for Societies. One element of Society is the Social System, relative to which Culture, Personality, and Organism are environments. The third column applies Parsons's scheme recursively to elements of the Social System. The parallelism between Parsons' action and Bennett's activity is shown in **Figure 6**.

Table 4 Parsons' systems of action
The columns are all hierarchies.

Action	Society	Social System
Pattern Maintenance	Cultural System	Institutionalized Cultural Patterns
Integration	Social System	Community
Goal Attainment	Personality System	Polity
Adaptation	Behavioral Organism	Economy

Figure 6 Parsons' and Bennett's Tetrads



(a) Parsons (b) Bennett

The hierarchical order in Parsons' action is the same as the hierarchical order of the systematics Tetrad. Descending the hierarchy,

- D. *Pattern Maintenance* is *goal*; in Society it is accomplished by the Cultural System, the societal component "concerned with the highest 'governing' of controlling patterns of the system"; in the Social System, by culturally determined institutions.
- C. *Integration* is *direction*, provided to the Society by the Social System and to the Social System by the Community.
- B. *Goal Attainment* is *instrument*, implemented for the Society by the Personality of individuals -- Parsons notes that "all action is the action of individuals," and for the Social System by the Polity. (The character of this component is given by the word "attainment," and not by "goal," which here has the narrow sense of specific objectives.)
- A. *Adaptation* is *ground*, performed for Society by the Behavioral Organism "which adapts to the broad conditions of the … physical environment," and for the Social System by the Economy. Adaptation partakes of the character of *goal*, but constitutes a 'lower' *end* in contrast to the 'higher' *end* of Pattern Maintenance.

Parsons places "high information" at the top of his hierarchy and "high energy" at the bottom, these two interacting via "cybernetic relations." In cybernetic control, he writes "systems high in information but low in energy regulate other systems higher in energy but lower in information." The sequence going down thus specifies a "hierarchy of controlling (informational) factors"; the sequence going up specifies the "hierarchy of conditioning (matter-energy) factors." Parsons' writings also make significant use of the pairwise interplays (to use Bennett's terminology) between his four action terms.

If one applies the 2:2 partition shown earlier in **Figure 2**(b) to Parsons' Tetrad for the Social System, the Tetrad divides into two lower terms, the economy and the polity, and two upper terms, the community and culture. The lower pair roughly correspond to what Habermas (1987) called "the system"; the upper pair roughly correspond to what he called the "lifeworld."

2.3.2 Planning (Ozbekhan)

A framework proposed by Ozbekhan (1971) for "planning as a hierarchical system" exhibits the hierarchical order previously shown in **Figure 6**, the downwards "cybernetic" control spoken of by Parsons, and the 1:3 partitioning of a system controlled at three levels of **Figure 3**(b). Ozbekhan's framework is summarized in **Table 5**. The normative level is concerned with determining ends: what "ought" to be done. The strategic level concerns the relationship between "known options and their possible alternative consequences," namely what "can" be done; this clearly requires some model of the entire control process. The operational level is concerned with implementation: the "how" of what is to be done.

Table 5 Planning Hierarchy

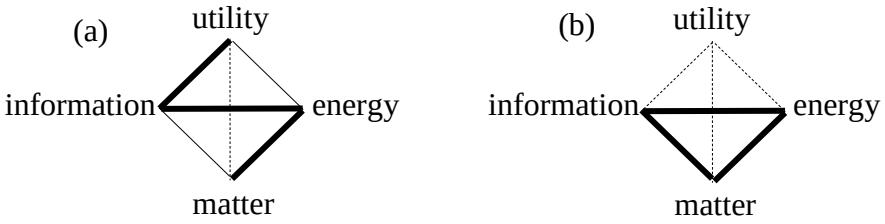
Bennett	Ozbekhan	
goal	Self-Organizing Level (Normative)	policy making
direction	Optimizing & Learning Level (Strategic)	executive decision making
instrument	Control Level (Operational)	administrative functions
ground	Process	

2.3.3 Matter-Energy-Information-Utility

Parsons' cybernetic hierarchy relates to a more abstract application of the Tetrad that answers the question that the systems theorist Stuart Kauffman once posed (1998): "Matter, energy, information ... what?!" Historically, these three categories emerged sequentially. Interest in the underlying nature of materiality can be traced back to the Greeks; thermodynamics, the science of energy, was developed in the 19th century; information, as a scientific category, was not recognized until the middle of the 20th century. Kauffman wondered what new categories might supplement this triad. A plausible answer – a 4th term – is "utility," whose conceptualization occurred at the same time as the conceptualization of information as a basic category. In the crystallization of the systems movement after WWII, Information (Communication) Theory of Shannon and Weaver (1949) formalized notions of information and Game and Decision Theory of von Neumann (1944) formalized notions of utility.

Bennett's tetrad organizes these four categories into a whole, shown in **Figure 7**(a): matter is *ground* (material cause), energy is *instrument* (efficient cause), information provides *direction* (formal cause), and utility is *goal* (final cause). Energy governs transformation of matter, information governs energetic interactions, and, in the domain of living systems the pursuit of utility – namely evolutionary 'fitness'– governs the generation and utilization of information. This upwards hierarchy, AB:BC:CD, which reflects the historical sequence of scientific acquisition of these basic categories, captures basic relations among them, and amplifies Parsons' cybernetic ideas.

Figure 7 Scientific Categories



The notion of "utility" as a fourth fundamental category in scientific explanation also bears on another question posed by Kauffman (1998): "What is required to be able to say that a system 'acts on its own behalf'?" The answer, again, is utility, whose evolutionary variant, "fitness," expresses the idea of action by a system on its own behalf or on behalf of similar systems. Utility is quintessentially biological, but matter, energy, and information are not restricted to the world of living systems. In evolution, utility is the end, relative to which information-energy-matter are means. **Figure 7**(b), which echoes **Figure 3**(a), reflects this idea.

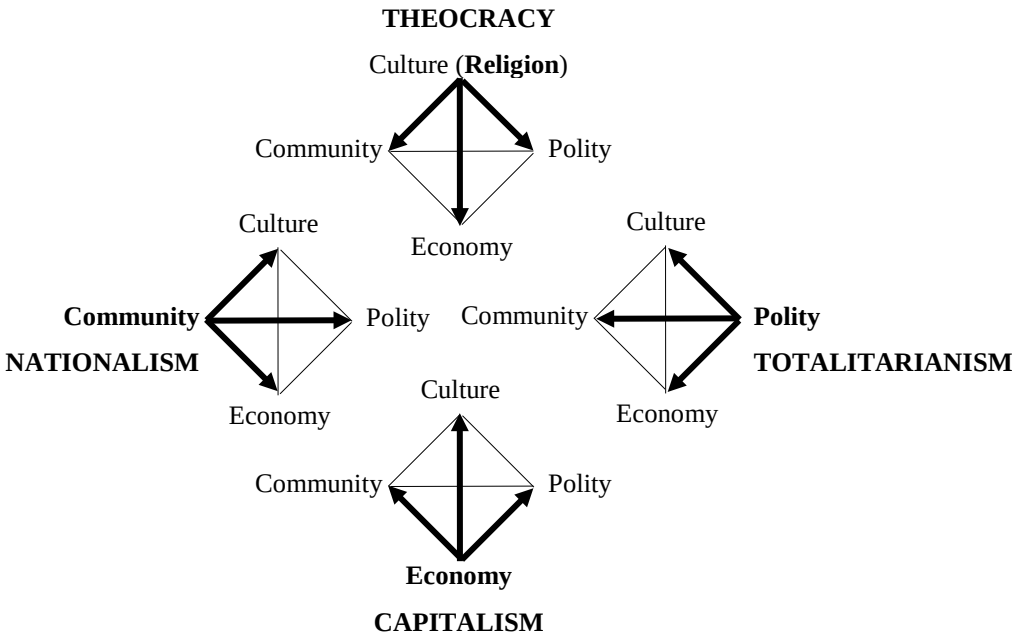
3. Other directed tetradic graphs

3.1 Leading parts

3.1.1 Societal fundamentalisms

Von Bertalanffy (1979) noted that some systems show "leading parts," elements that are more important than other elements. An ideal Society for Parsons would reflect some optimal balance of differentiation and integration of the Tetradic components. Each would have some autonomy, but each would also be constrained by the others. The presence of a leading part, however, would represent the dominance of one element over the others. The "fundamentalisms" produced by the hegemony of each element of Parsons' Tetrad are shown in **Figure 8**. For example, in **TOTALITARIANISM**, Polity (Instrument) is the leading part. This graph would be written as BA:BC:BC.

Figure 8 Leading parts & fundamentalisms



3.1.2 Feedback Control

A leading part does not have to represent a distortion; it may alternatively represent centralization. For example, *direction* is the leading part of error-controlled feedback systems, exemplified by the thermostat, shown in **Figure 9**, whose graph is **Figure 10**. Note that the lineal sequence (ignoring feedback) of *goal-direction-instrument-ground* is the hierarchical order for the Tetrad, and that the centrality of *direction* for feedback control accords with this term – thermostat – being used as emblematic of this system.

Figure 9 Negative feedback (thermostat) system as Tetrad

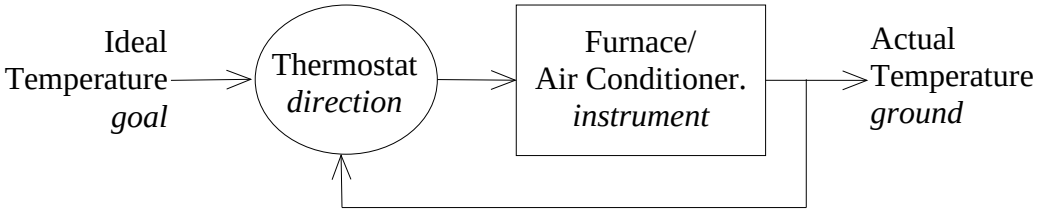
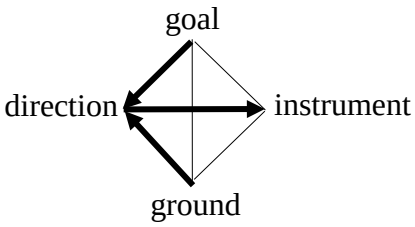


Figure 10 Thermostat system

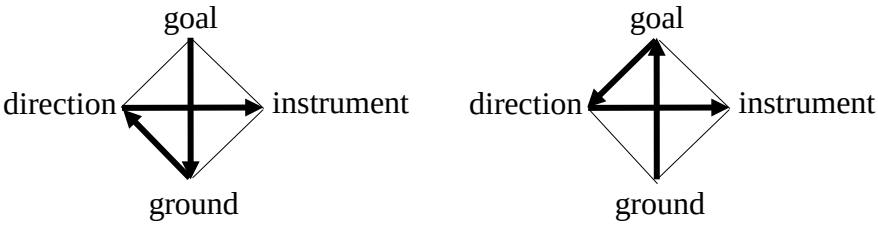


3. 2 Lineal paths

3.2.1 Control, problem solving

Another interesting – and simple -- type of graph is a lineal order of elements. For example, "control" and "problem-solving" have similar lineal graphs, DA:AC:CB and AD:DC:CB, respectively, as shown in **Figure 11**.

Figure 11 Control, problem solving



(a) Control (b) Problem solving

James G. Miller (1965) writes about the first of these:

> Every adaptive decision is made in four stages: (a) Establishing the purpose or *goal* whose achievement is to be advanced by the decision; (b) analyzing the information relevant to the decision [*ground*]; (c) synthesizing a solution selecting the alternative action or actions most likely to lead to the purpose or goal [*direction*]; and (d) issuing a command signal to carry out the action or actions [*instrument*].

"Adaptive decision" is here called "control." In this process, *goal* is compared to *ground*, and the difference between them is fed into the *direction* subsystem to yield instructions to *instrument*. One can augment this path by incorporating the fact that *instrument* alters *ground*, after which the process repeats. This lineal path might also be said to characterize negative feedback control as an alternative to **Figure 10**

Problem-solving is similar to control, except that it begins with a *ground* that is problematic. This *ground* is compared to a *goal* which articulates what might be preferred. While control is initiated by the intention to achieve an explicit ideal that is potential; problem-solving is initiated by the desire to correct something that is *actual*. While the transition to direction and then instrument are identical in both control and problem-solving, beginning with -- that is, emphasizing -- the *actual* (in problem-solving) is quite different from beginning with the *ideal* (in control). In the language of political change, the problem-solving orientation motivates ameliorative reform; control represents the aspirations of utopian or revolutionary action.

3.2.2 Genesis of control

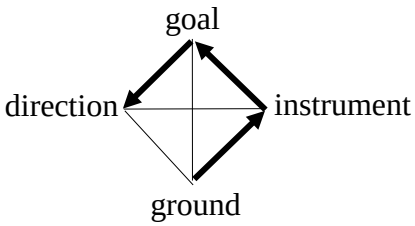
In **Figure 3**(b), control is represented as an *instrument-direction-goal* triad that governs some *ground* that is being controlled, and in **Figure 11**(a), the sequence of steps through which control is implemented is specified by a lineal graph. Both of these figures are essentially "synchronic," describing a control system that is already present. How this system comes about – its "diachronics" -- is also of interest, and can be modeled by the Tetrad.

Control comes into being historically. There is first some underlying process or *ground*, then the possibility of control through some *instrument.* One might posit that *instrument* initially is blind, with external (natural) selection causing the survival of instrumental responses which are fortuitously effective. At this stage, there is no internal representation of the effectiveness of instrumental action. Natural selection preserves those responses which are adaptive and thus performs the role of *goal*, but this performance is external to the system. If there is time for several possible responses by the *instrument* to be tried, it would be valuable for the system to have some *internal* representation of states that are viable or optimal. If such a representation exists, one can imagine *instrument* trying different actions randomly, sticking with an action that achieves the *goal* but randomly trying another action otherwise. This is "trial and error" learning; in Ashby's terminology (1952, 1956), "Hunt and Stick Regulation." If memory that stores successful responses to different environmental challenges is added, the use of such memory to guide action is a primitive subsystem for *direction*. This evolutionary story is summarized in **Table 6**, and the graph showing the sequential addition of terms is shown in **Figure 12**.

Table 6 Evolutionary genesis of control

Stages	
4. ground-instrument-goal-direction	Hunt & stick regulation with memory
3. ground-instrument-goal	Hunt & stick regulation
2. ground-instrument	Adaptation through natural selection
1. ground	--

Figure 12 Genesis of control



A more advanced instantiation of *direction* would be a subsystem that explicitly modeled the controlling process and its outcome. In the hierarchical order of the Tetrad *goal* is the "highest" term of the system, but from the perspective of genesis of control, it is *direction* which is the highest emergent of evolutionary processes.

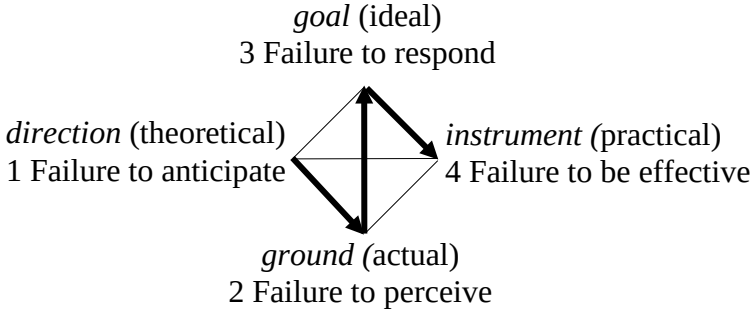
One might see the sequence of **Figure 12** in higher organisms in the relation of instinct, emotion, and intellect to body. Body is *ground*. Instinct is *instrument*, the repertoire of successful evolutionary adaptations. Adding emotion internalizes *goal*. Adding intellect provides *direction*. In MacLean's (1990) triune-brain model the evolution of the brain proceeded in this sequence: first instinct and motor functions (reptilian brain) emerged, then emotional functions (paleo-mammalian brain), then intellectual functions (neo-mammalian brain). In the neural net (NN) scheme of Approximate Dynamic Programming (Lendaris & Neidhoefer 2004), there are three components that play the roles of *instrument, goal*, and *direction*, namely the "controller," the NN component (*instrument*) that interfaces directly with the controlled system (*ground*), the "critic," the NN component (*goal*) that assesses expected utilities, and the "model," the NN component (*direction*) that models the effects of the controller on the controlled system.

3.2.3 Diachronic adaptive failure (Diamond)

Systems do not always successfully adapt. They may fail to control what needs to be controlled; they may fail to solve problems that need to be solved. Synchronic adaptive failure might be attributed to errors in specification of what is (*ground*), what should be (*goal*), how what should be might be accomplished (*direction*), and the means by which this can be achieved (*instrument*). Errors in any of these can produce failure.

Diachronic adaptive failure, however, begins with failure to anticipate the future, an inadequacy of theoretical understanding. Beyond this failure, there may be the failure to perceive what is actually occurring, or to respond to what is perceived, or if there is a response to the perceived gap between actual and ideal, the response may not be effective. This scheme, from Jared Diamond (2005), is shown in **Figure 13**.

Figure 13 Diachronic adaptive failure



4. Summary

Because of limitations of space and time, this survey can only sample the large number of Tetradic directed and undirected graphs that are possible and briefly comment on the meanings that can be associated with this small sample. A more expansive treatment of the Tetrad, and other categories of systematics and their interrelationships, including the analysis of hypergraphs, in which relations can link more than two elements, is a task for future work.

Whether there are other archetypal tetradic schemes that are substantially different from Bennett's Tetrad must be left as an open question. If there are such additional schemes, one would ideally like to know whether there could be some overarching framework that integrates these multiple schemes. Bennett's Tetrad of *ground-goal-direction-instrument* was based on intuition, not on an empirical exploration of four term systems, nor on a deductive approach based in theory. Nonetheless, the idea captured in this 4-term system represents a deep insight. This is demonstrated in the exemplification of this Tetrad by a wide variety of applications. Only a few applications are provided in this paper, but this sample shows that this structure is relevant to the work of such diverse thinkers as Ashby, Arrow, von Bertalanffy, Diamond, Habermas, Kauffman, MacLean, Miller, Parsons, and especially Peirce.

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