The Nature of Change: A Systems Theory Approach to Causality

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Abstract

Causality is pivotal to understanding the nature of change. The literature on causality, however, appears to ignore the idea that the whole is more than the sum of the parts. When real things are viewed as multi-dimensional (attributes and parts that constitute a whole), interaction, I claim, must also be viewed as multi-dimensional. In this paper, I propose that change occurs in certain ways according to the structure-organization-process (S-O-P) model that I describe. Some of the ideas mooted herein are, on their own, not controversial, however, when taken as a sum, a novel approach emerges. The structure-organization-process (S-O-P) model provides a way for understanding:

Structural change as *individual effects* to attributes (S);

Organizational change as *categorical effects* to parts (O); and

processual change as *universal effects* to wholes (P).

The S-O-P model heralds a new way of looking at the cause-effect relation by providing a means for predicting the diversity of effects that ensue from an interaction event. The S-O-P model is offered as a general organizing principle as it can be applied to closed, open and social systems.

Keywords: causality; change; systems theory, general organizing principle

Introduction

The Newtonian concept of change views real happenings as linear; for example, the simple collision between hard atoms that is often described as the billiard ball view of interaction. Simple collisions between simple objects can lead to prediction. Combine two chemicals and we know the outcome. Dynamic change, on the other hand, involves a multitude of variables. Real world happenings can be chaotic. We cannot predict the weather, when an earthquake will hit or the behavior of a hurricane; the number of participating variables are too vast to model.

I propose that the humble billiard ball has been much maligned. A billiard ball is, like all other instances of reality, constituted as a multi-dimensional object. In this vein, Betalanffy (1968:55) suggests that "the whole is more than the sum of the parts". If Betalanffy is correct, then the effects that ensue from a causal event must be different for the parts than the whole. However, the literature on causality appears to only address wholes.

In this paper, I propose that change occurs in certain ways according to the structure-organization-process (S-O-P) model that I describe. The S-O-P model was initially proposed by Maturana and Varela (1987:47) who explain that "… [an] organization denotes those relations that must exist among components …" and "… structure denotes the components and relations that actually constitute a particular unity …" While Maturana and Varela (1987:28) do not pursue a specific discussion about process, they setout to understand the role of cognition as "the universal nature of doing".

Some nine years later, Capra (1996:156) offers a synthesis of the systems theory literature (in particular, Maturana and Varela's contribution) by setting out three criteria for a living system: the pattern of organization, the structure and the life process. While Capra concentrates his discussion on living things, the idea of self-organization behind the concept of structure-organization-process is one in which a process[self] organizes [its own] structure. The structure-organization-process (S-O-P)model that I describe has its genesis in these ideas. However, I use the terms structure-organization-process more generally as I apply them to closed, open and social systems.

If we wish to understand causality, then we must start by determining what it is that is subject to change, that is, "what is a real thing?" I propose that real things can be described as having four attributes (properties, values, shape and efficacy), two parts (tangible structure and intangible organization) and one whole (that resides in four-dimensional spacetime).

Next, I look at the cause-effect relation and offer a systems theory view where inputs interact to yield outputs (inputs-interact-output). Having already identified what an input is (a multi-dimensional real thing), I then determine the quantity of inputs allowed in an interaction event. I propose that only two real things can enter into an interaction event and the two interacting particulars must be equal, but opposite (tangible matter and intangible force). I further resolve that the cause of interaction must reside in the intangible force.

When interaction between two multi-dimensional things occurs, interaction itself, I assert, must also be viewed as multi-dimensional. To understand the outputs that emerge from a multi-dimensional view of interaction, I examine the effects that occur when attributes interact, when parts interact and when wholes interact. The S-O-P model I describe provides away to understand:

structural change as *individual effects* to attributes (S);

organizational change as *categorical effects* to parts (O); and

processual change as *universal effects* to wholes (P).

To facilitate a deeper analysis of the S-O-P model from a broader readership a full description of the model is warranted. However, due to space constraints this paper provides only a skeletal description for the S-O-P model. In this brief description of a complex model, many assertions are evident. Some of the ideas mooted herein are, on their own, not controversial, however, when taken as a sum, a novel approach emerges. The S-O-P model, I claim, heralds a new way of looking at the cause-effect relation, and thus, the nature of change. I expect a lively debate to resolve the many issues that the model gives rise to.

The Nature of Reality

Before any ideas about change can be put forward I must clarify what it is that is subject to change. Change occurs to real things. This section describes what I mean when I say *real things*. I refer to my propositions about reality as the *dual-world hypothesis*. The dual-world hypothesis claims that:

real things are distinguishable according to four attributes (properties, values, shape and efficacy);

there are two kinds of equal, but opposite, real things (tangible and intangible), that have equal, but opposite, parts (structure and organization); and

real things are wholes that exist in four-dimensional spacetime.

From this point forward, I refer to real things as particulars to indicate that I am referring to both tangible and intangible real things.

Particulars can be described by four attributes

Following Weissman (2000:26–27), I assert that particulars can be described by their properties, values, shape and efficacy. However, my treatment of these attributes differs slightly to Weissman.

First, real particulars are constituted by their properties (2000:26–27). It is the properties of a particular that enables particulars to be known. Properties on their own are universal (e.g., weight, length, mass, etc.), a set of related properties are unique (e.g., element shave four related properties – the quantum numbers), and an instance of a particular within a unique property set is a unique particular (e.g., the element hydrogen).

Second, I propose that all properties have a numerical value. In order for a property to be discernable it must exist; thus, it has a numerical value of one and is countable (Lowe, 2003:78). I reject the idea mooted by Weissman (2000:28) for a qualitative value or no value. Color is often used to explain qualitative characteristics. However, different colors reside at a specific point along the light spectrum and can be measured. Any point in spacetime has a value. Qualitative values, I propose, have numerical values, even if it is by virtue of their singular existence. If a property has no value, then it does not exist. Further, a set of related properties have a valid range of values (that are relevant for the property set), for example, the valid values for the principle quantum number.

Third, properties have shape; for example, a line has one-dimensional shape. If a particular has more the one property then its shape is evident in the relations between its properties. Shape must comply with one-, two- or three-dimensions; as shape refers to the space a particular occupies.

Finally, all particulars have efficacy. Efficacy is evident in a valued property (or property set) with shape. A line, for example, is able to act as a highlight by underlining a word, joining two objects, as in a line on a drawing, and so on. A valued property (or property set) with shape has innate efficacy; what the property/ies depict/s about the ability of the particular. When a particular is employed, efficacy becomes manifest. For example, a 23 kg rock sitting on the ground has innate efficacy(potential), but its manifest efficacy depends on how the rock is employed; for example, as a weight to sink a boat, as an object to be thrown, or something I trip over.

There are two kinds of particulars with two parts

The idea that there are different kinds of particular sis not novel (Hoffman and Rosenkrantz, 2003:46). However, I claim that there are two kinds of particulars—intangible force and tangible matter. I further resolve that real particulars have two parts—a structure and an organization.

There are three options – single, duo or multiple –that we can explore in trying to understand how many different kinds of particulars there are. If the world was singular, then every particular that emerged would be exactly the same and aggregation into larger particulars would not be possible as there would be no other particular to enable aggregation. Aggregation is apparent in the universe. Conversely, a multi-modal world would prevent categorization of reality as there would be an endless supply of novelty. The effort to produce endless novelty would yield a chaotic universe; where nothing was comprehensible. Again, this is not the universe we see. Dualism, I contest, allows for similarity and difference. Thus, I propose that the world is inherently dualistic.

If reality is dualistic, then the two fundamental categories or reality must be equal in status. For one kind of reality to have more importance than another kind of reality suggests some pecking order. A pecking order requires some rule, or ruler, to state why one kind of reality is more important than another and under what circumstances the importance was enacted. Equality is the basis upon which stability occurs, for example, equilibrium. For a stable world to emerge, filled with two kinds of reality, the different realities must be equal.

The two different, yet equal, categories of reality, I suggest, must be opposite. Opposition allows for singularity to emerge, while at the same time establishing a maximum to the level of difference. Difference cannot be endless. Opposition allows for some difference (opposite) while at the same time limiting chaos. We often refer to particulars that are opposite as being polar opposite, where the difference, for example, between the North Pole and the South Pole, is the maximum. Any position less than the North Poleand the South Pole is less than the maximum difference between the two (opposing) particulars. When the difference between opposites is at its minimum, the two particulars become the same point. For example, the point where the North Poleand the South Pole become the same is at the Equator; north and south are undifferentiated. Opposition, then, can produce one-ness or whole-ness. One-ness is a singular universe and not the one we observe. Any one-ness we observe is the joining of opposite particulars. Opposition allows novelty to emerge from dual particulars (one-ness), while at the same time setting the maximum on difference. Opposition, I contest, controls the minimum (no-difference or one-ness) and maximum (opposite) levels of difference.

I recommend that the two equal, but opposite, realities be named tangible and intangible particulars. Tangible particular shave a physical presence, while intangible particulars are not physical and thus opposite. A tangible particular is one that can be touched, seen, picked up and so on: it has a physical presence, for example, matter. An intangible particular is something that has a non-physical presence, for example, a property, a dream or a force.

If there are two kinds of reality in the universe, and the universe depicts a one-ness, then one-ness is the joining of opposites. If we extrapolate this idea further, then tangible (matter) is the joining of opposites, and intangible (force) is the joining of opposites. Tangible matter is the joining of different properties to create a one-ness that occupies four-dimensional spacetime. The constitution of one-ness resides in the tangible properties(structure) and their intangible relations (organization) (Maturana and Varela,1987:47). Also, a force can, for example, act to repel or attract an object. As Newton advises, for every action there is an equal, but opposite, reaction (Newtonsee Hawking, 2002:744). This logic does not extend ad-infinitum to reveal a kind of reductionism. I propose that there are two kinds of reality (tangible and intangible) that have two parts (structure and organization that are evidenced by their properties and property relations).

Knowable particulars are multi-dimensional wholes

Real particulars, I claim are describable by their properties, values, shape and efficacy. When a particular has more than one property, it has a structure (properties) and an organization (property relations).Structure and organization combine to yield whole particulars. For causality to occur, real particulars must exist. Extant particulars, I suggest, are verifiable by their four-dimensional spacetime location.

Summary

The *dual-worldhypothesis* contests that real particulars have four attributes(properties, values, shape and efficacy) and come in two varieties (tangible and intangible) with two parts (tangible structure and intangible organization)to constitute a whole (that resides in four-dimensional spacetime). Effects can only be predicted if the initial conditions of a particular are known. Empirically, it is impossible to know the initial conditions for most particulars; especially open systems, as they are open to a constant flow of inputs and outputs (Prigogine and Stengers, 1984: 139–145). Theoretically speaking, however, the initial condition of a particular, I assert, is contained in its equal, but opposite, parts (as described by their properties, values, shape and efficacy) that reside in four-dimensional spacetime. The following will show that, from a theoretical point of view, effects can be predicted by utilizing this description of the initial condition of real things.

A Systems Theory View of the Cause-Effect Relation

Change emerges from the relation between cause and effect. The cause-effect relation is, typically, expressed as a cause leads to an effect ($c \rightarrow e$) (Kim, see Audi 1999:125). If we are seeking to explain *e* then *c* is pivotal. Whether change is novel or an alteration to something pre-existing, change is pivotal to explaining the universe. Thus, cause, as the instigator of change (effect),plays a central role, perhaps *the* role, in explaining the emergence of nature.

There are many views that take up different aspects of the cause-effect relation. I have two primary concerns with the current perspectives on causation. First, the examples cited are not analyzed into their constituent parts. The absence of proper analysis leaves embedded meaning in many of the proposals. On deeper inspection these proposals are rendered circumspect. Primarily, my objection resides in the idea that the effect is assumed to exist in a certain state prior to the cause affecting, that is, causing change. When this assumption is treated explicitly, an interaction event becomes evident. Second, a number of the causation theories require an observer or rely on causal constructs to explain causality. A circular argument is apparent with these theories. For example, negative causation requires an observer to determine what is positive and what is negative; the answer is entirely dependent upon the view being taken. In this section I put forward a theory for causality that I refer to as the *interaction hypothesis*. Causality, I claim:

occurs in a tripartite process of inputs-interaction-outputs;

requires two equal, but opposite, input particulars (intangible force and tangible matter);and

generates effect via the power of the intangible force.

Causality is a tripartite process

The idea of $c \rightarrow e$ is limited inasmuch as the true nature of the event is hidden. For example, to identify the cause we must understand the particulars that are present such that a cause can occur. When causality is viewed from a systems theory perspective, the event becomes a transaction of inputs-interaction-outputs; where various inputs (e.g., raw materials) are transformed by an interaction (e.g., a manufacturing process) to yield outputs(e.g., a pair of shoes). From this perspective, if we seek to understand causality then we need to first understand the nature of inputs, and then examine the transformation process. From a clear understanding of inputs and the transformation process we can finally embark on an analysis of outputs as effects.

Interaction has only two inputs

The contributing particulars to a causal event are referred to as conditions (Kim, see Audi, 1999:126; Weissman, 2000:25). The conditions must be deemed sufficient and necessary to the causal event(Davidson, 1999:432).

Interaction is the action between two things—inter-action. The Earth quaking and Los Angeles interacted to yield a devastated Los Angeles; the Sun's light and a building interacted to yield a shadow. Two input particulars are required to produce an output. It is impossible for more than two things to interact at any one time. While two pairs of particulars might interact with lightning speed, and, therefore, give off the appearance of multiple particulars in the one event, it is logically impossible for more than two particulars to interact at any one time. For example, if I lay four matchsticks (labeled A, B, C and D) on the table and attempt to have them all connect, I end up with four paired relations (A-B, B-C, C-D, D-A). A relation can only be between two particulars.

I claim that there are only two conditions to an interaction and both are necessary and sufficient for an effect to ensue. The two conditions are input particulars.

Input particulars must be equal, but opposite

The two input particulars, I propose, must be opposite—an intangible force and tangible matter. A tangible particular cannot act with another tangible particular and an intangible particular cannot act with another intangible particular. For example, a rock cannot interact with a glass window by itself; a rock requires a force to create a collision with the glass window. A moving rock is the intangible force that breaks the tangible window. Likewise, information cannot enter my mind without some force, such as reading, causing the information to be received by me. It is only in opposition that an effect can ensue.

In other words, only one particular can occupy apposition in spacetime. If there can only be two input particulars in an inter-action, then every interaction is, essentially, a collision between the two input particulars; a fight to occupy the same position in spacetime. When one particular has more force than the other particular it wins the fight (collision) and is, therefore, deemed to be the cause (intangible force) of the effect. The two particulars must oppose each other if they are to join (become one) in interaction. Essentially, I propose, that real particulars are not determinably classified as being either a force or matter, real particulars take up a certain role (force or matter) when they interact, depending on the circumstances of the event, for example, a rock can be a force when thrown or matter when I stub my toe.

Summary

The *interaction hypothesis* sets out a perspective for a causal event as comprising three facets: input particulars (the opposing things—tangible matter and intangible force—that participate in an event), interaction (the point where two particulars intersect or engage), and the effect or output from the interaction. The essential claim is that an effect ensues when opposite particulars interact. The notion of causality, then, is implied by the idea of interaction—this interaction (between tangible matter and intangible force)caused this effect (outputs).

The foregoing has examined causality in terms of an interaction event (inputs-interaction-effects), where two equal, but opposite, input particulars are needed. I have also determined that input particulars are multi-dimensional and can be described by their attributes, parts and as wholes. The next three sections examine effects in terms of what occurs when attributes interact, when parts interact and when wholes interact.

Structural Change is the Interaction of Attributes toyield Individual Effects

This section examines how we can determine if the effect of an interaction event is a new or altered particular.

If a particular can only be distinguished by four attributes—property, value, shape and efficacy—then some combination of these characteristics must remain intact for a particular to be considered analtered, as opposed to a new, particular. When a matrix of the four attributes is constructed between two interacting particulars, four kinds of change become evident: a substantive change (to properties), a quantitative change (to value), a formative change (to shape), and an effective change (to efficacy) (see Table 1). I set out six rules for determining the four kinds of attribution effects. I refer to these rules collectively as the *determination hypothesis* as they determine when a new or altered particular emerges from an interaction event.

Table 1: The propositions that comprise the determination hypothesis

Individual attributes	Substantive property		Ancillary properties		
	Property	**Value**		**Shape**	**Efficacy**
Property	✓ (rule 1, 2)	-	-	-	-
Value	✓ (rule 1, 2)	✓ (rule 3)	✓ (rule 4)	-	-
Shape	✓ (rule 1, 2)	✓ (rule 3)	✓ (rule 4)	✓ (rule 5)	-
Efficacy	✓ (rule 1, 2)	✓ (rule 3)	✓ (rule 4)	✓ (rule 5)	✓ (rule 6)
Kind of change	**Substantive change**		**Quantitative change**	**Formative change**	**Effective change**
Attribution effect	New property set emerges	New variety emerges	Altered particular emerges		
Level of change	Structural change (individual effect on attributes)				

Change to a particular's properties

A single property or property set characterizes a unique particular. Any addition or subtraction of properties to the property set of a specific particular will yield an intrinsically new particular that has a new property set. For example, when elements that belong to the same property set (e.g., hydrogen and oxygen) combine, they form a chemical (water) that belongs to a different property set (chemical compounds). When wax and a wick are combined, we have a candle, but wax on its own is not a candle. When fertilization between sperm and ovum occurs, a new particular emerges (a zygote) that has a new property set (sperm and ovum are haploid whereas a zygote is diploid) (Hartwell et al, 2004:80). When the Sun's light hits a building, a shadow emerges that has a different property set from the Sun and building. I refer to a change in the property set as a *substantive change*. This rule can be stated as follows:

> Rule1: If the effect (output) of an interaction is a particular with a different property or property set from the input particulars then a new particular is evident.

To clarify the extent of a substantive change, another rule can be added:

> Rule2: If the effect (output) of an interaction is a particular with the same property or property set as one of the input particulars, then any change must reside in some other attribute (value, shape or efficacy) of one or more of the properties.

Simply stated, these two rules infer that a new particular can only emerge if the property or property set changes; where property is a universal attribute and is distinct from values, shape and efficacy.

Change to a particular's value

Within any property set, one property is central to the identity of the individual particular. The central property could be called the *substantive property*; the property that gives a particular its core substance. Any other properties within the property set might be referred to as *ancillary properties,* the properties that are additional to the substantive property.

The value of a property specifies the unique instance of a property or property set, for example, oxygen has values that belong to the unique property set of elements. Any change to the value of the substantive property will yield a *substantive change* to the particular. For example, elements are comprised of protons, neutrons and electrons. A change to the number of electrons yields an ion of the same substance; a change to the number of neutrons yields an isotope of the same substance, but a change in the number of protons yields an entirely new element (a new variety belonging to the same property set). Thus, protons must be the substantive property of the physical elements and any change in their value yields a substantive change in the particular. This rule can be stated as follows:

> Rule3: If the effect (output) of an interaction is a particular with the same property or property set from the input particulars, but the value of the substantive property changes, then a new variety or particular (belonging to the same property set) is evident.

A change to the value of an ancillary property will yield an altered particular, for example, when the number of electrons increases or decreases in an atom, without a corresponding change in the protons, an ion of the same substance results (Ebbing et al, 2003:48). When a candle burns, the value of the height of the candle decreases. When a child grows it is the value of its properties that change (e.g., an increase in height and weight) and not its properties *perse*. A change of value signifies an alteration to the individual particular (that has a continuing property set). This rule can be stated as follows:

> Rule4: If the effect (output) of an interaction is a particular with the same property or property set as the input particulars, but the value of any ancillary property changes, then an altered particular (belonging to the same property set) is evident.

Identifying the substantive property for each property set is critical to determining if the emergent particulars are new or altered. A change to the value of a property or property set can be referred to as a *quantitative change*. A quantitative change is generated when the value of a property or property set (together with the valued property's shape and efficacy) has been altered.

Change to a particular's shape

The shape of a particular is determined by the arrangement of the valued property or property set. If the valued property or property set remains the same, but the shape changes, an altered particular is evident. For example, when I plunge my fist into a container of jelly, the mass of the jelly stays the same, but its overall shape has changed. A change to thecae of a particular could be referred to as a *formative change*; that is, a change that creates a differentform from the same valued properties. This rule can be stated as follows:

> Rule5: If the effect (output) of an interaction is a particular with the same valued property or property set, but a different shape from the input particular, then an altered particular is evident.

A formative change reflects a change only to the shape and efficacy of the valued property or property set.

Change to a particular's efficacy

The efficacy of a particular changes when a property or property set changes, when the value of a property or property set changes, or when the shape of a valued property or property set changes. The efficacy of a particular can also change without any corresponding change to the property, value or shape of a property or property set. Efficacy always changes as a consequence of interaction. For example, when I walk down the street and encounter another person, we both change course in order to avoid a collision. There is no change to the properties, value and shape of either person, but there is a change to their efficacy (their walking path). A change of efficacy alone could be referred to as an *effective change*; that is, the effectiveness of the particular is altered (i.e., its spacetime location). This rule can be stated thus:

> Rule6: If the effect (output) of an interaction is a particular with the same valued property or property set and shape, but a different efficacy from the input particular, then an altered particular is evident.

Efficacy will have a different effect depending upon whether the property, value or shape also changes.

Summary

A particular is distinguished by its property or property set, property values, shape and efficacy. If the property or property set changes, then a new particular is evident. If the value, shape or efficacy changes, but the property or property set remains the same, then the particular is an altered particular (unless the value change is to the substantive property, in which case a new variety is evident). For example, a river has flow, volume, length and geographic dispersion as its main properties. The river's flow may change from rapid to a trickle, the volume of water may increase or decrease, the length may expand or diminish and the geographic dispersion may widen or reduce, but the properties remain the same, thus the river's identity (as indicated by the name of the valued property set) remains the same. I refer to the kinds of change when attributes interact as *structural change*, given that related attributes establish the structure of real particulars. Structural change, I propose, results in *individual effects* to attributes.

A change to attributes can generate either a new property set or a change within a given property set. Thus, we need to next explore the kinds of change that can occur within a given property set, vis-à-vis other members of the same property set.

Organizational Change is the Interaction of Parts to yield Categorical Effects

In the previous section, I use a simple matrix between interacting particulars to determine the kind of change that occurs when attributes interact. In this section I again use a matrix to depict interaction between two particulars with equal, but opposite, parts. However, the interaction matrix must be multi-dimensional if the interacting particulars are multi-dimensional (by virtue of their property relations).

A multi-dimensional interaction matrix reveals twelve kinds of interaction arranged into a three-tiered (multi-dimensional) hierarchy. I refer to each level of the interaction matrix as simplex, complex and multiplex interactions. If interaction is responsible for generating all effects, then we need to understand the purpose or role (function) of each kind of interaction. I investigate the function of each kind of interaction from two perspectives—teleonomic and Cummins functions (Godfrey-Smith, 1996:14–20). I ask:

Teleonomicfunction: What is each interaction type *for*?

Cumminsfunction: What is each interaction type *good for*?

I propose that interaction between parts is *for* generating structural diversity(different forms), and *good for* endowing the universe with organizational diversity (different abilities or functions). I refer to this proposition as the *complexity hypothesis* as, I believe, it depicts the way nature enables a complex (heterogeneous and homogenous) world to emerge. The idea of structure-organization-process (S-O-P) mooted in this paper resides at many levels of this discussion. However, the complexity hypothesis sets out the primary form of the S-O-P model.

A multi-dimensional interaction matrix

The idea that interaction is a singular notion belie sour understanding that reality is multi-dimensional. Further, if the whole is different from the sum of the parts, then the interaction of parts must differ to the interaction of wholes.

Earlier, I state that interaction is always between opposite particulars (tangible and intangible); where the intangible particular is a force and the tangible particular is matter. I also propose that an intangible force has equal, but opposite, parts (e.g., attraction and repulsion) and tangible matter has equal, but opposite, parts (i.e., structure and organization). When opposite particulars (with opposite parts) interact, a matrix of interactions becomes apparent. Given that particulars are multi-dimensional, the interaction matrix must also be multi-dimensional (see Figure 1). Thus, various kinds of interaction are evident across three levels.

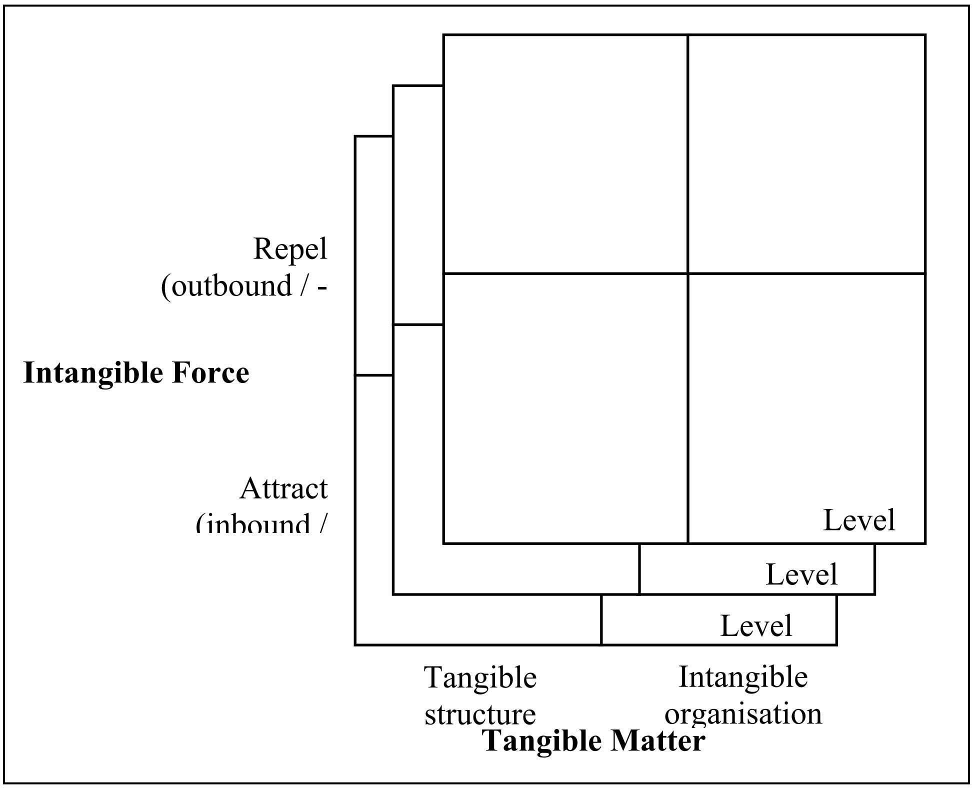

Figure 1: A multi-dimensional view of interaction

On the first level of the multi-dimension alinteraction matrix, there are four kinds of interaction (see Figure 1). The first level of interaction might be considered simple interactions; for example:

when an object attracts (e.g., when opposite poles of a magnet are placed together)(A);

when information attracts (e.g., an ordered pattern that emerges in a chemical reaction) (B);

when information repels (e.g., chemical disorder) (C); or

when an object repels (e.g., when similar poles of a magnet are placed together) (D).

It should be noted that the labels used in this example to depict a force—attract and repel—are those used by physicists. When the interaction matrix is used to reflect interaction for a living system, attract and repel might be depicted as inbound and outbound to reflect the forces that allow living systems to be open to their environment. The four kinds of interaction depicted in Figure 1 suggest that when a force affects a particular it can do so in four different ways. Following Bohm's (1980:210-211) understanding of complexity, I have named these four ways *simplex interactions* as they depict a simple (single-fold) relationship between the parts of interacting particulars.

The interaction matrix, thus far, represents the initial conditions that include the parts of a particular. Given that related parts generate a three-dimensional shape, the interaction between two multi-dimensional particulars (with equal, but opposite, parts) yields a multi-dimensional model of interaction that reflects all possible configurations within the interaction matrix (see Figure 2). I refer to the second level of the interaction matrix as *complex interactions*, as it depicts the relations between simplex interactions. Complex interactions are two-fold (Bohm, 1980:210–211). I refer to the third level of the interaction matrix as *multiplex interactions* (many-fold), as it depicts the relations between complex interactions (two-fold) (Bohm, 1980:210-211). All possible interactions, without duplication, reside in the twelve intersections depicted by the multi-dimensional interaction matrix (see Figure 2).

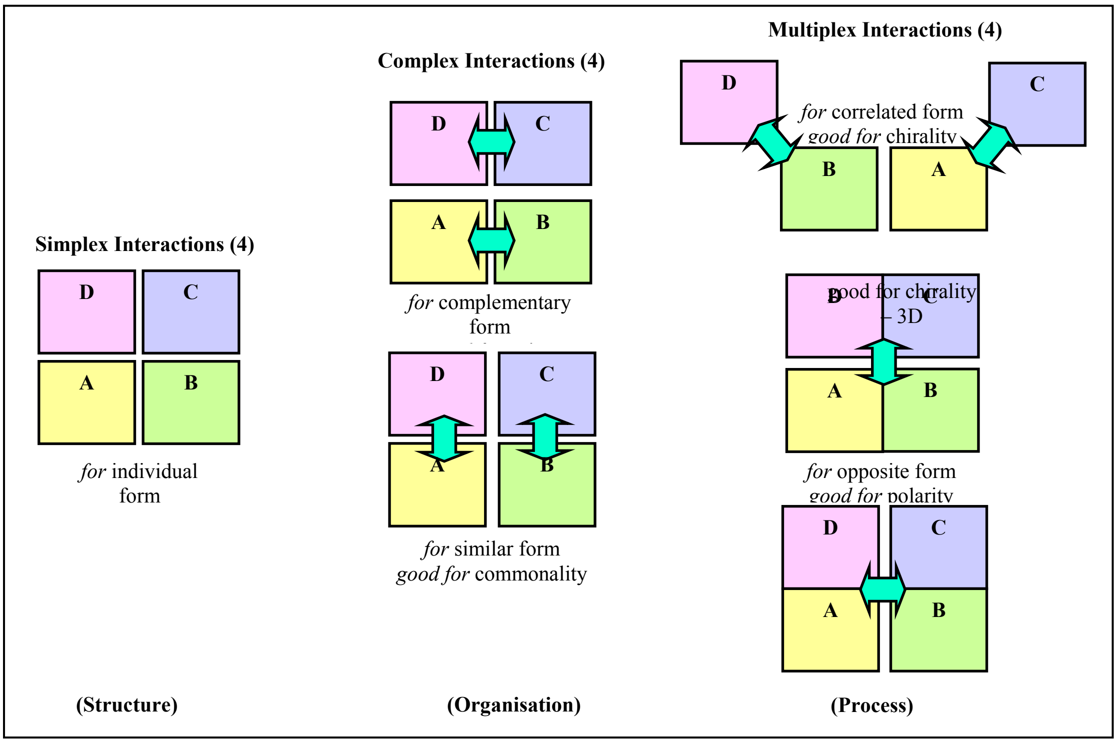

Figure 2: A multi-dimensional view of the interaction matrix with the teleonomic and Cummins functions noted

The following proposes that the interaction of parts (as depicted in the multi-dimensional interaction matrix) yields *categorical effects* given that parts represent categories within a particular.

Simplex interaction yields individual form and function

At the attribution level, the kind of change to a given property set is a change to the value of the substantive property. Considering that the substantive property confers a particular with its substance, any change to the value of this property will generate a substantially new variety. For example, when the number of protons increases, anew element emerges that belongs to the same property set.

I propose that the teleonomic function of simplex interactions is *for* generating individual forms; that is, simplex interactions are *for* generating different kinds of structures within a given property set. I further propose that the Cumminsfunction of simplex interactions is that they are *good for* endowing the universe with variety, which represents the first level of organization within the universe (see Figure 2).

I further suggest that there can only ever be four individual varieties within any given property set, as the first level of the interaction matrix depicts. For example, there are four kinds of elements, four kinds of DNA, and four kinds of attributes that describe a particular. While Margulis and Shwartz (1982:7) suggest that there are five kingdoms of living things, the first kingdom—monera—belongs to a different property set(prokaryote).

Complex interaction produces categorical form and function

The second level of the interaction matrix is complex interactions, because it adds simplex interactions together. At the individual attribution level, the second kind of change is a quantitative change to any ancillary property. A change to the value of any ancillary property cannot produce a new variety, so a different kind of change must occur within the property set.

Complex interactions result from simplex interactions being folded together. If individual varieties are folded together categories emerge. The four individual parts can be folded together to create four complexes. These complexes can be viewed as two sets of two (equal, but opposite), so I suggest that complex interaction yields two categorical forms—complementary (AB, CD) and similar (AD, BC) (see Figure 2).

The second level of the interaction matrix, I conclude, is *for* generating complementary and similar forms within a given property set; for example male and female are complementary forms within the property set of human beings, and black swans are similar to white swans within the property set for swans. I further recommend that the Cummins function of complex interactions (and, hence, complementary and similar forms) is that they are *good for* allow ingunity (one-ness) and commonality, respectively (see Figure 2). The second level of organization within the universe, I propose, represents two-dimensional functionality.

Multiplex interaction generates universal form and function

The third level of the interaction matrix depicts multiplex interactions, because it folds complex interactions together. I propose that the teleonomic function of multiplex interactions is *for* generating universal forms, on the basis that it folds categories together. I further propose that there are two universal forms—correlated and opposite forms. Correlated forms are evident inasmuch as each variety within a property set has a co-relation with the other varieties. Opposite forms are evident due to the opposite ways a force acts on a particular. I recommend that the Cummins function of multiplex interactions (and, hence, correlated and opposite forms) is that they are *good for* chirality and polarity, respectively (see Figure 2). Chirality refers to right-hand and left-hand that is correlated. Polarity can include positive and negative or north and south. The third level of organization within the universe, I claim, represents three- and four-dimensional functionality. Space is the third dimension that correlates properties, and spacetime is the fourth dimension that locates particulars in the universe (where polarity governs direction).

Summary

Interaction is not a single linear act, but a dynamic going on. Interaction itself is ineffable. We cannot observe interaction, only the inputs to the process and the subsequent outputs (effect). The *complexity hypothesis* proposes that the interaction between two multi-dimensional particulars (with equal, but opposite, parts) yields a three-tiered hierarchy of organizational change to allow a diversity of form with a diversity of functionality to emerge (within a given property set). The effect of *organizational change*, I propose, is *categorical effects.* The S-O-P model provides a way to predict the characteristics that differentiate particulars that belong to the same property set, and a way to understand their relationship.

This section of the S-O-P model has set out the range of effects that emerge from a given property set. We need to next investigate the kind of effects that result when whole particulars interact.

Processual Change is the Interaction of Wholes to yield Universal Effects

Thus far, I have described the kinds of change that emerge with attributes interact and when parts interact. To complete the S-O-P model, I need to set out the kinds of change that occur when wholes interact. This level of change refers to the production of whole new particulars.

Briefly, real particulars have an internal hierarchy as determined by their attributes that combine to create parts that join to yield a whole. When a matrix between two interacting particulars is set out, with the three levels that comprise whole particulars, we can identify three processes that produce three kinds of whole new particulars—universal effects(see Table 2):

When attributes interact, new individuals with the same property set (copies) can emerge—replicative change (S).

When parts interact, new categories of particulars that belong to the same property set(relatives) can emerge—relative change (O).

When wholes interact, new property sets (classes of new property sets—closed systems, open systems, social systems) can emerge—systemic change (P).

Table 2: The propositions that comprise the production hypothesis

Real particulars	Attributes (structure)	Parts (organisation)	Wholes (process)
Attributes (structure)	Produce new individuals (copies)		
Parts (organisation)		Produce new categories (relatives)	
Wholes (process)			Produce new universals (classes)
Kind of change	Replicative change	Relative change	Systemic change
Universal effect	Replication of attributes produces copies of same individual particular	Generation of a new part (relative) within a property set produces new categories	Emergence of whole new property set
Level of change	Processual change (universal effect on wholes)		

Closed systems are independent structures (like attributes, e.g., atoms): they rely on nothing to exits. Open systems are dependent organizations (like parts, e.g., organisms): they rely on closed systems to exist. Social systems are dependent processes: they rely on the relationship between closed systems and open systems (like wholes, e.g.,eco-systems).

I refer to the three kinds of universal processes that yield new particulars as the *production hypothesis,* as it depicts the kinds of processes that produce the range of particulars that inhabit the universe.

Conclusion

The cause-effect relation is pivotal to understanding nature. To date, the cause-effect relation has only examined particulars as wholes. Real particulars are multi-dimensional where the whole is more than the sum of the parts. I propose that interaction must be viewed as multi-dimensional. When interaction is viewed as multi-dimensional the effects that ensue are many and varied. A model describing the effects emanating from a multi-dimensional view of interaction has been outlined in this paper.

The S-O-P model can be difficult to follow. Level one(individual effects) reflects the four segments of the interaction matrix, level two (categorical effects) has the S-O-P model nested within (four segments on each of the three tiers), and level three (universal effects)aligns itself with the three tiers of the interaction matrix (see Table 3). A numerical version of the S-O-P model has been developed to facilitate case studies and provide insight into the way nature links the various segments and levels together (see Glassop, 2006a; 2006b). I believe that wherever there is order within a given property set the S-O-P model can be applied. To apply the S-O-P model to a given property set requires:

- Ascertaining what the two input particulars are, and their equal, but opposite, parts;
- Identifying the attributes that constitute the property set and specifying the substantive property; and
- Intimate knowledge of the S-O-P model, especially the computations for deriving the numerical version.

Table 3: Three kinds of change according to the S-O-P model

<table>
<tr><td>Interaction matrix</td><td>Structural change (4)
(individual effect
on attributes)</td><td colspan="2">Organisational change (12)
(categorical effect on parts
➔ form and function)</td><td>Processual change (3)
(universal effect on wholes)</td><td>S-O-P model</td></tr>
<tr><td rowspan="2">Multiplex interactions (Level 3 x 4)</td><td>Effective change
(to efficacy)</td><td rowspan="4">Quantitative change to ancillary properties</td><td>Different affect to whole:
opposite form (AD:BC, AC:DB)
good for polarity</td><td rowspan="2">Systemic change
(new universals, i.e., classes of property sets)</td><td rowspan="2">Process</td></tr>
<tr><td>Formative change
(to shape)</td><td>Same affect to whole:
correlated forms (AB:CD)
good for chirality</td></tr>
<tr><td rowspan="2">Complex interactions (Level 2 x 4)</td><td rowspan="2">Quantitative change
(to values)</td><td>Different affect to both parts:
complementary form (A:C, B:D)
good for unity</td><td rowspan="2">Relative change
(new categories, i.e., relatives)</td><td rowspan="2">Organisation</td></tr>
<tr><td>Same affect to both parts:
similar form (A:D, B:C)
good for commonality</td></tr>
<tr><td>Simplex interactions (Level 1 x 4)</td><td>Substantive change
(to properties)</td><td>Quantitative change to substantive property</td><td>Different affect to one part:
individual form (A, B, C, D)
good for variety</td><td>Replicative change
(new individuals, i.e., copies)</td><td>Structure</td></tr>
</table>

The S-O-P model has been used to provide a theoretical description for the construction of the Periodic Table. My analysis reveals a procedure for determining the quantum numbers, the locus of periodicity and the logic behind the unusual shape of orbitals. The S-O-P analysis of the Periodic Table also provides an explanation for twenty empirical anomalies (see Glassop,2006a; 2006c).

An analysis of the key features of Deoxyribose NucleicAcid (DNA) has also been undertaken using the S-O-P model. This analysis successfully describes the features that constitute the helical structure, together with correctly predicting that the number of genes per chromosome for *Homo sapiens* follows a power law (as a universal effect) (see Glassop, 2006a; 2006d).

The ability of a single model to provide a theoretical description for two fundamental, yet entirely different, aspects of the universe, I suggest, is enticing. However, the validity of the S-O-P model will only come from its in-depth description, wide-spread application and usefulness for generating predictions. I offer the S-O-P model as a general organizing principle (Barrow 1991:136).

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