How is a relational ontology (such as a formal learning model) formally relational? A phenomenological exploration of the semiotic logic of agency in physics, mathematics and biology

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Abstract: A phenomenological exploration of the distinction between a relational formal ontology (also called a process ontology) and a classical formal ontology (also called an object ontology) for modelling physical phenomena that exhibit relationally-mediated holism, such as phenomena from quantum physics and biosemiotics. Whereas a classical formal ontology is based on mathematical objects and classes, a relational formal ontology is based on mathematical signs and categories. A relational formal ontology involves nodal networks that are dynamically sustained through signalling. Nodal networks are systems of constrained iterative processes (dynamical nodes) that have individual semiotic agency within a matrix of determinate possibilities (a semiotic scaffolding). The nodal networks are hierarchically ordered and exhibit characteristics of deep learning. Clarifying the distinction between classical and relational formal ontologies may help to clarify the role of interpretative context in physics (eg. the role of the observer in quantum theory), the role of signalling in biological systems and the role of hierarchical nodal networks in computational models of learning processes in generative artificial intelligence (AI).

Keywords: Relational ontology; Biosemiotics; Category theory; Interpretations of quantum mechanics; Formal learning models

I was there;
when he drew a circle on the face of the deep
[Proverbs 8:27]

for whatsoever doth make manifest is light
[Ephesians 5:13]

In *de Doctrina Christiana*, Augustine writes: "All teaching is either about things or signs; but things are learned about through signs" (Augustine 1996: 2.2). If this be true, and if we follow the tendency in modern physics to absent all signs from the physical universe, will we not be left with an ontology of objects—as *things-in-themselves*—about which nothing further can be learned? And would this not become a false conceit obstructing *Theoria Physike,* because such a universe in-itself*,* from the very beginning, could not bring forth the possibility of learning?

Learning is growth. Increase[1]. Movement through limitation. Therefore, as counterpoint to the potential false conceit underwriting modern physics, let us suppose that the whole physical universe is open to processes of learning *from the beginning.*

How might we come to understand such a supposition?
Let this question become our *étude*.

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The phenomenological method of our *étude* is to perform a speculative thought experiment in *meta*-physics that might mark the distinction between a classical formal ontology that is governed by the binary logic of objects and classes (Whitehead and Russell 1910-13) and a relational formal ontology (Rosen 1991) that is governed by the threefold logic of signs and categories (Peirce *CP*). Here the term *formal ontology* refers to the formal mathematical basis of a given theoretical model of nature that is also taken as an interpretative framework for understanding nature in actuality[2].

The motivation for our *étude* comes from the current difficulty regarding the interpretation of phenomena in nature that are described by quantum theory (Smolin 2007; Maudlin 2019). The hypothesis for the thought experiment is that the difficulty with interpreting these phenomena in nature is a result of a category error regarding formal ontologies. Specifically, current theoretical

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[1] For metaphysical context regarding the notion of increase, see *I Corinthians 3.6* and *I Ching: 42*.
[2] For metaphysical context regarding formal ontologies in physics, see Maudlin (2019). According to Maudlin, a physical theory should contain a physical ontology that articulates what the theory postulates to exist as physically real. An ontology can be seen as an interpretative framework for understanding the *relationship* between representational theory and experiential actuality. In this context, physical ontologies might be further categorized according to the formal mathematical basis of the corresponding theory. Hence the term *formal ontology.*

formulations of the phenomena in nature are usually taken to fall within the interpretative category of classical formal ontologies (also called object ontologies). As a result, interpretations of formal theory are not well suited for understanding purely relational phenomena of physical bodies, such as entanglement and interaction-mediated determination (eg. measurement). A relational formal ontology might be understood as a better fit for interpreting these phenomena in nature because the formal entities of the formal ontology behave *analogously* to physical bodies in nature[3].

One key feature of a relational formal ontology, that distinguishes it from a classical formal ontology, is that the relation between what is represented (actuality) and the representation (theoretical model) is part of the model. Therefore, relational formal ontologies are constitutionally open to inter-relations with their environment and these relations are not separable. Rather, they belong to the *interpretative context* of the theoretical model, a context that is undisclosed in a classical formal ontology.

A relational formal ontology can be reduced to a classical formal ontology under certain limiting conditions, such as infinitely fast mediation of signalling ($c \rightarrow \infty$) combined with the absence of indeterminate action ($h \rightarrow 0$). However, a classical formal ontology cannot be expanded into a relational formal ontology because of formal relational aspects that cannot be articulated by classical binary logic.

In our *étude* we will start within a naïve interpretative context that assumes a classical ontology of formal objects, such as the classical formal ontology of Newtonian mechanics that is underwritten by differential calculus. By pushing against the constraints of the given formal ontology (i.e. phenomenologically bracketing these constraints), and with some poetic license, we will attempt to bring into view formal aspects of relational ontology that are inexpressible within classical ontology. We will then recapitulate the description as a relational formal ontology.

0. *Telos*

You may want to skip this section until after having read the rest of the paper.

In the beginning is a reference to the end. Upon completion of this *étude*, the following distinctions may have determinable significance for you. (Or they may not.)

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[3] It should be noted that a *relational formal ontology* is characterized by the *relationship* between mathematical theory (represented form) and physical actuality (experienced world). This is a different metaphysical context from some forms of relational physics that are based on classical formal ontologies, such as some forms of Shape Dynamics as described by Vassallo, Naranjo, and Kolowski (2022). A key differentiating feature of a *relational formal ontology* is that the identity of a form (eg. a shape in Shape Dynamics) does not come from either the relata (*things* related) or the relations among the relata. That is to say, the whole is more than its parts and their relations. Much of relational physics, including Shape Dynamics, is formally restricted to the relational category of *Thirdness* (eg. spatial structure), without consideration of formal relational aspects of *Secondness* (eg. subsistent relation as relation to qualitative Otherness) and *Firstness* (eg. return relation as the formal identity operator).

In the context of physics, a sign is a directed relation whose identity is given for a host. Thus, the sign is a relation whose identity is in relation. A host mediates a categorical duality that brings its delimited interior into relation with an exterior that is not delimited in the same sense that the interior is delimited. As a result of the categorical duality, the interior of the host can receive repeating forms as spatiotemporal patterns from its exterior when they are synchronized with repeating forms as spatiotemporal patterns in its interior.

The correlation of a particular exterior form and a particular interior form is the directed relation of a sign for the host. The sign is a vehicle of mediation that points toward a sign-object, where the sign-object is the exterior form that is coming into distinction for the host. The sign-vehicle points away from the interior form within the host that is the sign-interpretant representing the sign-object for the host.

When a host receives a form from its exterior through a sign, it becomes an agent for semiotically informed action that results in the transmission of another form to its exterior that can be received by another host as a sign. The semiotically informed action of the host is an interior activation that is constrained by what has already been formed for the host. This formal constraint is the condition of possibility for semiotically informed action. Within this formal constraint there is an irreducible indeterminacy that grants semiotic freedom to the host when it acts. Thus, the action of a host can be formative, creating new forms from the given conditions of possibility.

Hosts can be either marked or unmarked. To be marked means that a given host is taken by the theory to represent a particular and actualized agent in the world. The host that is marked is taken by the theory to belong to the category of subjectivity. The other unmarked hosts are taken by the theory to belong to the category of objectivity. Subjectivity is particular and actual; objectivity is general and formal.

A marked host can be taken to be a spatiotemporal index or origin for the ordering of relations within a networked community of image hosts within its interior. The marked host synchronizes the network of image hosts through signalling. A signal is a spatiotemporal ordering of signs that is also a sign. Signalling occurs through the action of exchanging quanta of energy that can be received as signs by the image hosts. Thus, a marked host governs the formative processes of image hosts by communally constraining the image hosts to the given conditions of possibility that constitute their semiotic scaffolding. Governance involves formed laws of action as well as indeterminate randomness (arbitrariness) that comes from unsynchronized action that is consequently unformed for the community of image hosts.

A marked host can be taken as a formal model of a physical body as the subject. The marked host establishes a context for the subject. The networked community of image hosts, within the marked host, then model the formative dynamics of the constituting components of the physical body, such as cells within an organism. The constituting

components become image-objects that come into distinctive formation in relation to one another within the given subject as a semiotic context.

A marked host can also be taken to be an image host for a marked host at a higher level of hierarchical ordering. For example, a marked host that is a formal model of a cell can also be taken as an image host for a marked host that is a formal model of an organism constituted by cells.

Within a given level of the hierarchical ordering, the action of a marked host is a potential sign for other hosts of the same level within the hierarchy. A potential sign is actualized through communal signalling. Signalling, which is governed by the next highest level of the hierarchy, is the formative process of semiotic freedom. Semiotic freedom is the creative play of distinguishing distinctions that occurs between the categories of the marked and the unmarked, of exteriority and interiority, of objectivity and subjectivity. Semiotic freedom is enacted by hypostases which are hosts in relation whose ambiguous marking represents an openness to final cause.

In the context of physics, marking is given by an indeterminable first cause that exceeds any formal model of nature. Hierarchical ordering is open to an indeterminable final cause that also exceeds any formal model of nature. The indeterminacy of the first cause and of the final cause grants semiotic freedom to the agency of hosts throughout the hierarchy of a semiotically informed model of Nature.

1. Identifying Subsistent Relation[4]

In the first instance, signs might be taken as things that signify something else for an interpreter[5]. For example, smoke can be taken as a sign of fire by someone. There is an inherent relation implicated by the sign—when the sign is taken to be an objective thing—that is essential to its very nature. The sign both is itself as a signifying thing—a signifier—and it *also* points beyond itself, to what it signifies for the interpreter of the sign. In Peircean semiotics (*CP*), this inherent relation is reflected in the definition of a sign as a *vehicle* of representation that can mediate the relationship between an exterior *object* (that which is represented by the sign) and an internal response or *interpretant* (that which is signified by the object for the interpreter).

In classical physics, by contrast, things—represented by *classical formal objects* or states—are usually taken to rest in-themselves, without any necessary relation to something beyond[6]. It is precisely because a classical object rests in-itself that it can be abstracted from context and made into an isolated and determinate object. That is not to say that classical objects don't have

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[4] For metaphysical context regarding subsistent relation, see White (2022).
[5] Ultimately, a sign is a relation within a threefold semiotic logic. In our *étude*, however, we will start by referencing things-as-objects with the intention of moving our attention away from the objects and towards the relationality that exceeds objectivity.
[6] For metaphysical context regarding the distinction between objects and signs, see Deely (2009).

relations; indeed, they are always embedded in systems of relations[7]. Rather, it is to say something about what is assumed regarding the nature of relationship in physics. Namely, relations are taken to belong to classical objects as variable properties that are separate from the *object-in-itself*, rather than essential to the constitution or very being of things as given objects. We might even say that classical physics tends to assume all relations are relations of *separateness*[8] and that things, as given objects, are separately distinguished, each in itself, *a priori* and from the beginning. Even when the phenomena in nature do not have this property of separateness, as is the case with the phenomena described by quantum theory, the underlying theoretical formulations continue to assume that such phenomena can be modelled by formal theories whose foundational mathematical objects are defined by relations of separateness.

However, I don't suppose it is at all clear yet what I might mean by "relations of separateness", or why it may be problematic to assume all formal relations in physics belong to this category. A counter example might be helpful here. To this end, consider the experience or *phenomenon* of time. As we experience time, there is an inherent movement or flow *from* the past *to* the future, where the past is determinate in some sense and the future is indeterminate in some sense. Let us call this flow *procession.* In the present moment, we might take this moment, marked as "present", to be the *host* of "presence" through which the past is falling out of or relinquishing presence while the future is coming into or assuming presence. This way of speaking is quite elusive, however[9]. Particularly with regard to the notion of a "host" whose very nature is to receive its presence from the past and then give up that presence to the future. Doesn't the host thereby lose its status as a viable *thing*, since as soon as it appears, it disappears; it never rests in being, so to speak? The host is more like a boundary or a *limit*, a limit whose very essence is to be overcome by procession.

Separateness also involves a limit[10]. The limit of proximate contact between two contiguous things in space, for example. But the essence of this limit is that it is not overcome, it does not *process*, it remains within itself, unlike the case with time.

Another, different kind of example is necessary now for us to be able to begin to distinguish our terms of reference[11]. Consider the nature of words. As signifiers, words are physical things or events in the physical or material world, such as marks on a page or audible sounds from my mouth. But words also point beyond their material presence to something *other*, namely, to that

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[7] For metaphysical context regarding systems of relations, see Zwick (2023).

[8] For a discussion of separateness in the context of physics, see Howard (1985).

[9] For metaphysical context regarding the elusive nature of time, see Augustine (2008).

[10] In our *étude*, we are particularly focussing on the limiting form of relationships when the relata (the things that are brought into relation) are taken to be in immediate proximity. That is to say, we are interested in limits as signs of continuity (Zalamea n.d.). The "null operator" (i.e. infinitesimal differential operator) of Newtonian calculus, for example, is the limiting form of the relation of separateness within the category of spatial extension. For further context, see *The Proximity of Light: a deconstruction of space* in Rogers (2022).

[11] The use of multiple particular examples as image-objects in order to reference a unifying general notion that is in the process of coming into determination is a methodological approach characteristic of semiotic logic. Once named, the general notion assumes its identity from the multiple contexts (eg. mathematical categories) of the image-objects to which the name is applied. In mathematics, this methodological approach is contingent upon making a distinction between mathematical notions (as generals) and mathematical objects (as particular formal models of general notions). This distinction comes from the semiotic principle that no general notion can be modelled by a single image-object alone. For further context, see Zalamea (n.d.).

which they signify. In this sense words also process. This procession is commonly called signification or *reference*. Words *refer*. They give up their physical or material being in-itself, so to speak, in order to manifest an immaterial meaning or signification. We might say that a word is a *host* through which the given embedding in a physical or material domain is given over to an embedding in an immaterial mental domain. But in this case, perhaps, the host itself does not seem quite so elusive as in the case of time because the host manifests in the material domain, as text or speech for example. However, the material domain is *categorically different* from the immaterial domain and the host mediates this categorical difference by way of procession. Yet the two categories never come into proximate contact by way of a limiting form of separateness (Levinas 2002). Indeed, it is very hard to depict the *limit* or boundary between a physical object as a signifier and its immaterial signified as a mental concept in terms of the null relation of separateness. (Unlike the case with time, where we might be inclined to represent the limit between the past and the future by a relation of separateness as is the case in differential calculus, even if we thereby falsely characterize the *phenomenon* of time.) The physical thing as signifier is a material object or event *in-itself-for-another* that does not always disappear from the material domain when it becomes a word, unlike the present moment that always disappears from presence. Rather, the physical thing assumes a role as signifier of something other, something that is categorically different from the material object that it is in the material domain. The word, as host, rests at the limit or boundary between the material and the immaterial domains, a limit whose very essence is to be overcome by procession in order to refer.

Now we have brought into distinction two types of procession. In the procession of time, a host gives up its presence from a determinate past to an indeterminate future. In the procession of signification, a host gives up its embeddedness in the domain of the given material world to become immersed in a new, categorically different, domain of immaterial re-presentation. Bringing these two distinct types of procession into an analogical relation hopefully now allows us to distinguish the limiting relation of *procession* from the limiting relation of *separateness*.

The relation of separateness, as a proximate relation or *limit*, is like the spatial contiguity between two classical objects as things that belong to the same domain or *category* (eg. the archetypal category of space). The objects somehow are taken to "rest in themselves" and the relation of proximity is a passive limit conceived as a timeless "null zone" or "zero point" with no content or interiority. *With the relation of separateness, no movement or change ensues with respect to either of the objects as objects or the relationship of contiguity as relationship.* Through procession, on the other hand, a *contingent* host mediates a categorical difference between two domains by way of proximity and substitution. Proximity, as a null zone or zero point, is overcome by substitution through which the host gives up a determinate aspect from one domain to an indeterminate aspect in the other domain. The host sustains a *limit* or boundary between the two categorically different domains, a limit whose essence is to form *a directed* relation *from* one domain that is somehow determinate *to* the other domain that is somehow indeterminate[12].

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[12] The directed relation is the aspect that distinguishes mathematical category theory from set theory. As a result of the directed relation, *category theory includes notions that cannot be articulated in set theory*. Duality is an example of such a notion, where duality comes into determination by way of mutual relations between distinguishable categories. Much of current mathematical category theory involves only discrete categories or "universal sets". In these mathematical contexts, the elements of the set (as mathematical objects) can be separated from their mutual

With separateness, the limiting relationship of contiguity (namely, direct contact) is a zero point that is separate or distinct from the classical objects of a given category and functions as another *form* of object that belongs to that same category but has no content or quality (an *empty form*)[13]. In procession, the limiting relationship of proximity and substitution *subsists* through the host and cannot be separated or distinguished from the host; it is a *movement* from one category to a different category.

Having brought into relational distinction two particular instances of procession (time and reference), let us now try to formulate *relationally* what we mean by procession using a third instance that might be taken to serve as an iconic sign[14]. That is to say, the third example will be taken to be both *particular* as an instance of procession and *general* with regard to our intention to extract a common form of *likeness* found all three particular instances, the likeness of subsistent relations.

For our third example, consider a *physical body*. More specifically, consider a physical body as a thing in the material world that is de-limited by a physical boundary—such as a biological cell[15]. Let the physical boundary— such as the cell membrane—mediate a categorical difference between the physical interior and the physical exterior of the body.

Let us take the material domain embedding the physical body as the *given ground*; this is a category of sameness about which nothing further is distinguished or articulated. However, it should be noted that this given ground always already establishes a *context* by back-grounding materiality as given. Suppose we represent the boundary of the physical body—such as a cell membrane—as a closed circle embedded in a two-dimensional plane. This representation is a *formal model* of the physical body in which the circle stands for the boundary—the delimiter— and the plane upon which the circle is inscribed stands for the embedding domain of materiality—the given ground. Further, let the relation between the exterior of the physical body

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relations (as directed relations). The elements of the "universal set" form a closed mathematical system at the level of elements, but the whole system, as a category, remains open, by way of directed relation, to other categories. In this mathematical context, a classical formal ontology can be constituted. However, is it also possible to consider the elements of the "universal set" as categories in which case they operate as signs rather than formal objects *per se*. The mathematical context in which categories are constituted by signs, which in turn can be considered as categories that are constituted by signs, and so on, is the context for constituting a relational formal ontology. A relational formal ontology provides a new perspective on the nature of continuity because the indefinite continuum of semiotic logic (i.e. the logic of signs and categories) involves three categories of relation in relation. For further context on the indefinite continuum of semiotic logic, see Zalamea (n.d.).

[13] Since classical objects all belong to the same category, they are qualitatively *the same* within that category. Therefore, they can be treated as formally identical and lacking interiority or variable *property*—that is to say, they can be treated as belonging to the same *class*. The limiting form of separateness then becomes a passive null interval within that category—a passive *empty form*. For example, within the category of spatial extension, the limiting form of separateness can be taken to belong to the category of spatial extension, even though it does not fully belong to that category, because, as a zero operator, it refers to the negation or absence of all classical objects. However—and this is the key point—the act of representing or determining the zero operator within a given class as an element of the given class brings closure that *excludes the possibility of a categorical difference*. See also footnote 10.

[14] The method of using an iconic sign to reference a general notion involves foregrounding sameness. The foregrounding of sameness is the creative principle whereby a category can come into determination as a unifying principle of the general notion. In the context of our *étude*, the general notion is *subsistent relation*.

[15] For context regarding the formative processes of distinguishing in a biological cell, see Rogers (2024).

and its interior be a relation of *procession*. In our formal model, this relation of procession can be represented by a directed arrow that points *from* the exterior *to* the interior as shown in Fig. 1.
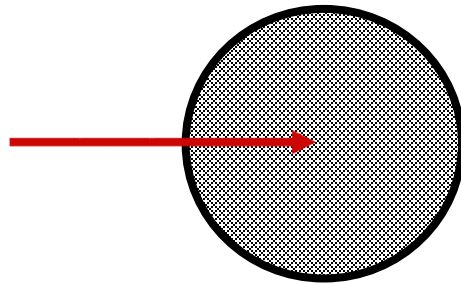
Figure 1: A marked host
This formal model identifies a physical body by its boundary (black circle) and distinguishes the delimited *interior* of the physical body (marked as shaded) from the undelimited *exterior* (unmarked) by a directed relation of procession (red arrow). The delimited interior is *determinate* and the undelimited exterior is *indeterminate*.

In the formal model, the bounded circle identifies the physical body. That is to say, the circle is the *identifying principle* of the body. The two-dimensional space in which the circle is embedded represents the *given ground*, the category of sameness to which the physical body belongs— namely, the category of materiality. This grounding is the context for the formal model. Within the given ground of sameness, the arrow, by virtue of its directedness, *distinguishes* a domain that is delimited—the interior—from a complementary domain that is undelimited—the exterior. That is to say, the directed arrow *breaks the symmetry* of sameness characterizing the given ground. The broken symmetry distinguishes or *marks* an interior *in relation to an exterior to which it is interior*. The delimited interior we might call the *determinable* category; the undelimited exterior we might call the *determining* category. Interior and exterior have no inherent *categorical differentiation* except by way of this relation of broken symmetry. We might say that the relation of procession is the *action* of breaking symmetry and this action is the *formative principle* for a new categorical distinction between the marked determinable interior and the unmarked determining exterior within the overarching context of the given ground which belongs to the category of materiality. Importantly, with this perspective, the determining exterior is not the same as the given ground. The determining exterior is not given *a priori*, so to speak; rather it comes into distinction by way of the marking of the determinable interior[16].

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[16] At this point you might be inclined to think that we are over-specifying the distinction between the interior and the exterior because the closed circle already differentiates the two spatial domains as distinct. Why introduce the directed relation as a necessary aspect of distinguishing? Notice, however, that the distinction is apparent to us just insofar as we are not embedded in the ground of the two-dimensional space in which the circular figure is inscribed.

2. Distinguishing Distinctions

The formal model depicted in Fig. 1 presents to us a figurative image of a marked *host*. The host is identified by way of its closed or delimited boundary (black circle) within the category of the given ground. It is also marked by the subsisting relation of procession (red arrow) that tells us the host exists *in relation to something else* to which it is second, namely the exterior. This directed relation distinguishes two new categories—determinable interiority and determining exteriority—within the beginning or given category of the background embedding space (i.e. materiality). We might be inclined to say that determinable interiority and determining exteriority are *sub*-categories of the given grounding category (i.e. materiality). This would be misleading, however, because without a host there is no distinction between determinable interior and determining exterior. The host *creates* this distinction between two complementary or dual categories through subsistent relation.

The creative act of distinguishing breaks the symmetry of the given ground. It involves a *movement* from the exterior *E* to the interior *I*. Complementary to this broken symmetry we can infer another, implicit movement in the *opposite* direction—*from I to E*. This oppositional movement restores the symmetry of the given ground, giving us complementary or dual processions, namely *The Receptive* and *The Creative* ("The Great Treatise" in *I Ching*) as shown in Fig. 2. The processions are dual in the sense that each comes into determination *in relation to the other*, and neither has the potential for determination (or existence) without its dual.

In our case, distinction comes from *beyond the given context*. By way of counterpoint, let us instead suppose that the act of distinguishing can be accomplished within the given context, that there is something about the given ground that allows for the possibility of distinguishing differences, that the given ground is more than the passive two-dimensional *space* represented in Fig. 1. This "something" is a quality of receptivity that is purely relational within the given ground and that can only be referenced once the given ground is transcended by way of relation with a *different category* that subsists as a complementary category to receptivity—namely, the category of *The creative*.
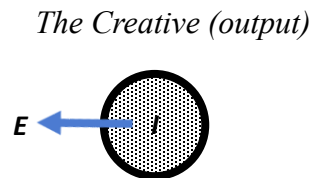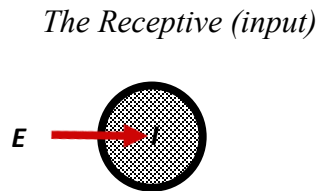
The Receptive (input)

E ⟶ ◯

The Creative (output)

E ⟵ ◯

Figure 2. Duality through broken symmetry
The Receptive is taken to be a procession *from* the determining exterior *to* the
determinable interior, like an input. *The Creative* processes in the *opposite* direction, like
an output. *The Creative* and *The Receptive* are an archetype of duality.

In relation to the identified host as the index, *The Receptive* is a movement *out of* the determining
exterior *into* the determinable interior—the exterior *gives* as *source* and the interior becomes the
receiver. By contrast, *The Creative* is a movement *out of* the determinable interior *into* the
determining exterior—the interior *gives* as *source* and the exterior *receives*. These two
movements belong to two different *categories* of responsive determination.

For the marked host as index, the more familiar relation of *The Creative* moves from a
determinate source to an indeterminate terminus, like the relation of cause and effect. With each
successive output, a source brings a terminus into determination. Most of modern physics, and
all of classical physics, is premised on privileging this type of procession which thereby plays the
role of *universal time*. If we further postulate that the originating source (eg. the "Big Bang") and
the completing terminus (eg. the "Big Crunch") also belong to the category of the determinate as
empty forms, then universal time reduces to formal relations of separateness *within a given
ground of broken symmetry*. The broken symmetry of the given ground occludes the *oppositional
procession* that comes from the complementary or dual category of procession that has been
subverted and this occluded dual procession manifests as timeless external governing laws
combined with some form of external randomness and/or spontaneous generation in the formal
model.

In modern physics, the relation of *The Receptive* is difficult to depict precisely because of an
assumption that the given ground is determinate; therefore, *all* is interior and there is no

determining exterior in relation to the determinable interior[17]. In other words, there is no procession of time without a complementary dual procession that acts in opposition to time. Because physics does not formally represent time as categorically different from space (Unger and Smolin 2015), it also does not formally represent the complementary dual procession. But one cannot conclude from this that physical time is an ontological illusion; the illusory nature of time was assumed from the outset *in the formalism*.

To get a handle on the dual procession that is complementary to time and invisible in modern physics, we might notice that the directed relation we started with (see Fig. 1) enacts the logic of a conditional relation:

> If **E** then **I**
>
> where **E** represents the determining exterior (unmarked) and **I** represents the determinable interior (marked)

We might interpret this conditional relation in two different senses which belong to two different categories as contexts. In the first instance, we might say that **E** *causes* **I**. This sense belongs to the category of *effective causation* that is time-like as discussed above. **E** determines **I** by way of effective causation. In the second instance, we might interpret this conditional relation as telling us that **E** *signs* **I**. This sense belongs to the complementary category of *formative causation* that is space-like. With this sense or context of interpretation, **E** offers up to **I** the possibility of a sign whose significance must be worked out by **I** in its relation to **E**. **I** is able to distinguish distinctions in **E** as signs that have significance for **I**. The difference between these two senses is that, in the first instance, the exterior is determining the interior in the way that effective causes determine resulting actions. This context might be called *the world as action*; it is governed by formal laws. In the second instance, by contrast, the interior brings aspects of the exterior into determinate distinction to the extent that those exterior aspects *inform* the interior as a responsive agent. This context might be called *the world as formation*. The world as action is marked by the procession of *The Receptive* insofar as **I** receives effects from **E**. The world as formation is marked by the procession of *The Creative* insofar as **I** becomes an agent that can creatively distinguish or mark aspects of **E** in relation to **I**[18].

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[17] For an exploration of the limitations of such an assumption, see *On the Embodiment of Space and Time: Triadic logic, quantum indeterminacy and the metaphysics of relativity* in Rogers (2022).

[18] At this point you might be brought up short by the logical progression above because something quite strange has happened. Starting from the image of a host within a given ground of sameness (Fig. 1), we inferred a broken symmetry that brought into view *The Creative* and *The Receptive* as complementary movements that are distinguished through their opposing directed relations. In this way, the given category of sameness (i.e. materiality) became the receptive ground for the creation of a categorical distinction between the determinable interior and the determining exterior. The determinable interior of the host identified *The Creative* as processional output in relation to *The Receptive* as processional input. Then we relinquished the given ground of materiality to foreground the relationship between the two types of procession. We called the procession from determination to indetermination *Output* (determining) and we called the procession from indetermination to determination *Input* (determinable), taking the original figure (Fig.1) as our guide. *Then we switched the roles of the two opposing relations*. As a consequence, we created *two distinct grounds as contexts*. The world as action is marked by the movement of *The Receptive* and the world as formation is marked by the movement of *The Creative*. In other words, we relinquished the given ground whose symmetry had been broken by procession (the category of materiality) and pivoted on the

Through substitution, the given ground brings these two different causal domains as two complementary or *dual* categories[19]—effective cause as marked by *The Receptive* and formative cause as marked by *The Creative*—into a threefold relationship that characterizes a delimited host as shown in Fig. 3.
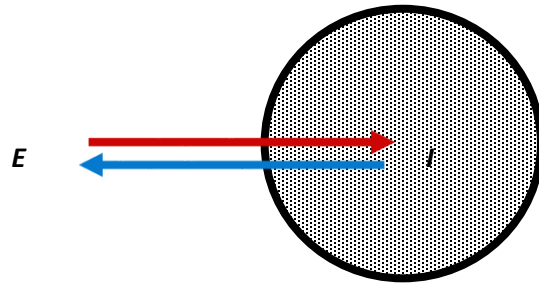

Figure 3. Characteristic form of a host as a mediator of signs
A delimited host (black circle) mediates the categorical difference between a determining exterior *E* and a determinable interior *I*. The host brings into relation two complementary categories of causation: Effective causation as marked by *The Receptive* (red arrow) and Formative causation as marked by *The Creative* (blue arrow). The two complementary categories come into determination as a relational *duality*.

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reconstituted symmetry of relational duality to identify two distinct groundings—effective causation and formative causation—united in a threefold relationship with the host. This is one example of a type of logical movement that is not possible when the given ground of modern physics is assumed to be fully determinate. We will encounter other examples of new logical moves as our *étude* unfolds.

[19] Mathematically, these two categories correspond to the logic of sets and the logic of distinctions. The foundational principles of the logic of sets is described by Whitehead and Russell (1910-1913), for example. George Spencer-Brown (1969) provides a foundational approach to the logic of distinctions in *Laws of Form*. David Ellerman (2024) discusses the categorical duality of sets-as-collections and distinctions-as-partitions within the context of a classical formal ontology in his paper *A Fundamental Duality in the Mathematical and Natural Sciences: From Logic to Biology*. In our *étude*, we are attempting to use these two categories, taken as a duality, to approach the notion of an indefinite continuum. See also footnote 10.

3. Abstracting General Forms from Particular Differences

The sign is coming into view in our *étude* as the terminus of a progression which begins within the given background category of *the Same*; where the original or first category of materiality plays the role of an index or context to which everything else is related. Because space is an archetype for categories of sameness, we represented this category as *spatial* as in Fig. 1. Within the passive grounding of space, we then identified a *movement* of procession that plays the role of the *Other* in relation to the passive grounding of space that is the *Same*. This movement came into view by way of a finite host which is delimited by a closed boundary. In relation to *space*, procession is a movement that is *time-like,* moving from determination to indetermination. Procession creates and breaks symmetry, thereby implying a dual movement that is *reference-like*, moving from indetermination to determination. Time and reference form a duality whose archetype we called *The Receptive* and *The Creative*. Then we shifted the index *from* the given background category of space *to* the delimited host as a *mediator* that entrains the reconstituted symmetry of the dual movements of procession thereby bringing into proximity two different categories, namely, effective causation (of *The Receptive*) and formative causation (of *The Creative*).

As a new indexical context, let us now take the host-as-sign-mediator (Fig. 3) to be the *first* through which we can recapitulate the description. Let us call this *marking*, where to be marked is to be taken as an index for the ordering of relations. Recapitulation through marking involves reformulating the description through a formal model of *signs* as given (based on the semiotic logic of three), rather than a formal model of *space* as given (based on classical binary logic). In order to accomplish this, however, we must let go of the assumption that the grounding of materiality is *complete*. That is to say, the category of material cause does not fill out the full measure of physical bodies—physical bodies, in their actuality in the world, are more than mere material substance. In fact, no category can be complete in this sense, because a totalizing background of sameness *cannot bring forth difference*[20].

Therefore, when we take the host-as-sign-mediator to be the *first*, or marked index, to which everything else is related, we can no longer model it formally as bounded by the *spatial* figure or image of a passive closed circle as in Fig. 1. Instead, we must model it as a delimited process or *repeating interval* that involves *delimitation in space and in time*. To be delimited in space means there is a closed boundary that is the condition of possibility for distinguishing interior from exterior as discussed above. Delimitation in space is *extension*. To be delimited in time means there is a repetition of movement or change that is the condition of possibility for manifesting form as pathway or tracing or pattern. Delimitation in time is *duration*. A simple formal representation of such a repeating interval—the relation of *Return*—is a closed circle that processes in time as shown in Fig. 4. Let us use this simple formal representation to explore the way in which the indexed host becomes a mediator of signs[21], anticipating that the principles found here might also be actualized in arbitrarily complex physical processes such as processes of biological formation[22]. A mathematical example of this formal representation is the plane formed by the complex numbers.

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[20] For metaphysical context, see Somers-Hall (2012).
[21] For further context for this simple formal model, see *Spacetime as a Formal Semiotic Process* in Rogers (2022).
[22] For further context regarding biological formation, see Rogers (2024).
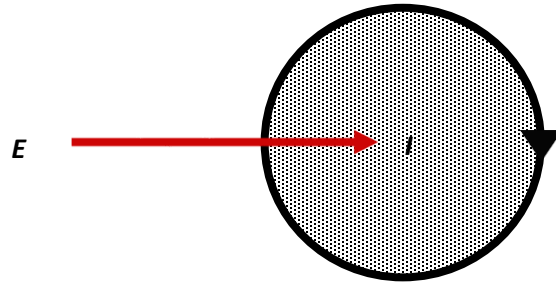
Figure 4. *Return* **as the identity operator of a host**
The marked host is a repeating interval that is delimited in space and time. Delimitation in space is represented in the figure by the finite closed circle. Delimitation in time is represented in the figure by repeated cycles around the closed circle. The relation of *Return* is represented by a continuous procession around the closed circle. The relation of procession (red arrow), as broken symmetry, marks the host's interior in relation to its exterior.

The host, as marked index, provides a rhythm of synchronization by way of repetition of temporal cycles around the spatial boundary. It also provides the basis for distinguishing interior from exterior by way of procession from the exterior to the interior[23], where the interior is marked by the "givenness" of the indexed host.

Now let us suppose that within the interior of the marked host, there is an image of the host. Like the host, let us also represent this image as a closed circle of continuous procession. Further, let the image process *in synchronicity* with the marked host. The marked host provides the measure of temporality by way of its repeating rhythm and the image of the host endures within the marked host as a component of the marked host *insofar as its pattern of temporal repetition is a harmonic interval of the marked host*. For example, it may process once, twice, or three times around its closed loop for each procession of the marked host.

Let us suppose the indexed host is embedded within the category of materiality, although now this category does not completely ground[24] the formal model as was the case in Fig. 1. What belongs to the category of materiality is the image of the host, while the given, indexed host *exceeds* the category of materiality as will become apparent below. In other words, let us take the image of the host to be a *material process of repetition*—a repeating dynamical process of a particular material complex such as rotational spinning, vibration, or a cyclical channel of

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[23] For example, a branch cut as a directed relation from infinity to zero in the complex number plane in mathematics.
[24] This is similar to the way that real numbers do not completely ground the complex number plane in mathematics.

chemical reactions. Let us call this repeating material process an interior *component* of the marked host.

Because the interior component is material it can be taken to be in relation with material elements in the exterior through effective causation as is usually the case in physics. By this we mean that a given external element can impact the internal component through successive relations of cause and effect that involve the transfer of energy from the given external element as *source* to the internal component as *receiver*. Such an effective causal pathway, shown in Fig. 5, is time-like as discussed above.
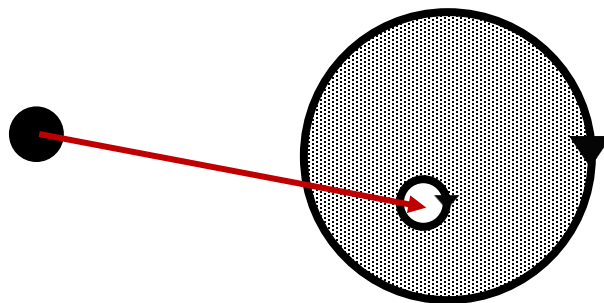

Figure 5. Effective causal pathway from external element to internal component
An external element (filled black circle) is the source of energy that can be transmitted by an effective causal pathway (red arrow) to an internal component (open circle) within an indexed host (large shaded circle). The indexed host and the internal component cycle in synchronicity (represented by black arrows on their respective boundaries).

Let us take the effective causal pathway starting from the external source element to be energy conserving, by which we mean that any input energy that is received by a given material element is immediately passed to the next, proximate element without absorption. This is equivalent to saying that the material elements in the exterior have no interiority whereby they might absorb energy[25]. (The term "element" is used to refer to such empty forms, while the term "component" is used to refer to images of the host that possess some form of interiority). However, let the internal component that is an image of the indexed host be an exception to this rule because this internal component can absorb a quantum of energy that will increase its rate of repetition *as long as it remains in harmonic synchrony with the marked host*. In other words, an external element is a material element that immediately transmits any energy that it receives, while an

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[25] For purposes of simplicity and clarity, we are assuming that the exterior material elements have no interiority and are therefore "empty forms" in which the input matches the output *immediately*. More generally, there may also be systems of synchronization in the exterior with their own time signatures.

internal component is a *pattern* of material movement that has *multiple possible modes* (in this simple case the modes are different frequencies) as *determined by the marked host*.

For most instances, the energy that is transmitted from the external element to the internal component will not affect the synchronization of the internal component. That is to say, the internal component will remain in the same mode or frequency. The internal component will act like a material element insofar as the inputted energy will be immediately outputted as if the internal component were an empty form (i.e. as if the internal component had no interiority). However, if the frequency of the transmitted energy matches the frequency of synchronization established by the indexed host, then the internal component can absorb a quantum of energy and thereby become *activated*. In this simple example, activation manifests as repetition at a higher harmonic frequency than the baseline state of synchronization. An activated component sustains a self-contained dynamical process—*in the context of the marked host*—that can serve as an ordering principle around which the internal component *forms* in relation to other internal components of the marked host.

The activated component then becomes an *interpretant* of the sign-signal that came from the material element. That is to say, because of the effective causal pathway from the material element to the internal component through which a quantum of energy was transferred, the activated component can be taken to *refer* to the material element in the exterior which caused the activation, *in the context of the marked host*. However, the internal component does not refer to the material element as a particular material element in the exterior. Rather, it refers to a spatiotemporal *pattern* in the exterior—coming from some spatiotemporal *process* characteristic of the material element—that matches its own pattern of repetition (in this case a simple temporal frequency). Thus, the activated component is able to distinguish a *class* of material processes in the exterior that have the property of generating sign-signals that match the frequency of the internal component. In this way, the internal component distinguishes a *general form* in the exterior that has multiple particular manifestations. The act of distinguishing general forms is called abstraction. The marked host, as a mediator, is the condition of possibility for abstracting general forms from its environment by way of the activation of its internal components.

How is this possible? The ability to abstract form comes from the fact that the marked host simultaneously participates in two categories of order understood as two hierarchical levels: the lower order of effective causation (*The Receptive*) and the higher order of formative causation (*The Creative*). In our formal model, the lower level of order—the level of effective causation—was taken to be fully explicated. It was applied univocally to the category of exteriority. Thus, the material elements in the exterior were taken to be "empty forms" that immediately transferred input energy to output energy without the possibility of absorption. Such a procession of energy is *temporal*. Likewise, the internal component participated in the level of effective causation insofar as the frequency of procession of the energy was not a harmonic interval of the frequency of synchronization of the indexed host. However, once activated by a matching frequency of procession, the internal component is able to participate in a higher level of formative causation insofar as it *refers* to a pattern of abstraction in the exterior. This level of order is implicate in the sense that it involves abstracted patterns that have to be worked out by the internal component through its relations to the exterior (and to other internal components).

Time-like procession involves regression to a *first cause*. For example, a given material element comes into determination by being affected by a prior material element that was affected by a yet prior material element and so on to the beginning of determination. Reference-like procession, as signification, involves progression to a *final cause*[26]. For example, a given sign first distinguishes one particular instance of its signified, then another, then another until the unifying formal pattern of abstraction comes into final determination. The internal component mediates regressive and progressive causal procession[27] through duality as shown in Fig. 6. This duality offers a simple example (Rogers 2024) of metaphysical indeterminacy as semiotic freedom (Kull 2023).
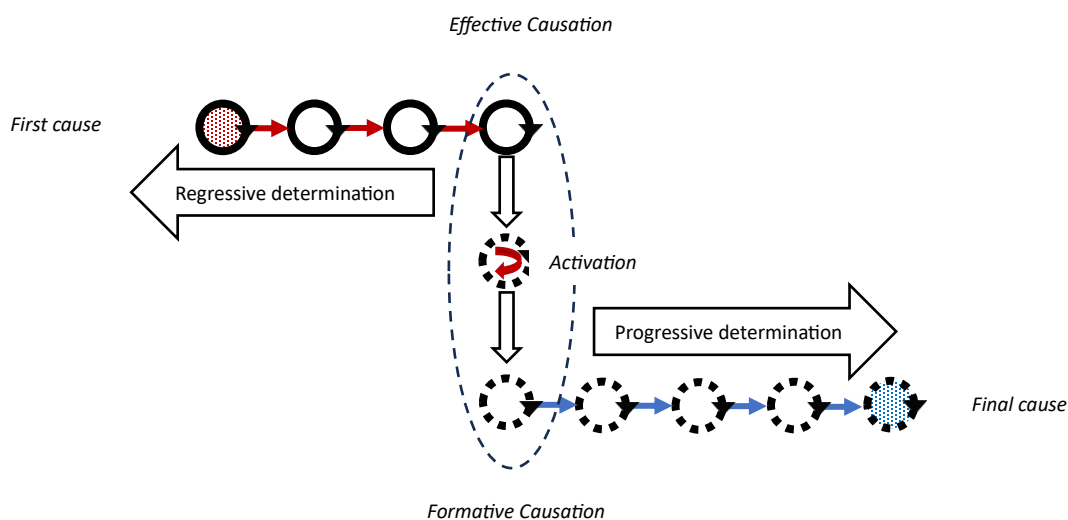

Figure 6. Regressive and progression determination of an internal component
Without activation, the internal component (solid circles) remains within the category of effective causation (temporal succession) involving regressive determination to a marked First cause. The event of activation allows the internal component to also participate in a higher-level order (dashed circles) within a different category of formative causation (signification) involving progressive determination to a marked Final cause.

Formative causation includes both formed aspects and formative action. While perhaps not yet apparent, it will turn out that effective causation, which involves regressive determination, is governed by formed aspects that provide lawful rules which come from *that which has already been formed*. These formed aspects also constitute a "semiotic scaffolding" (Favareau 2015) or "matrix of possibilities" (Makridakis 2024) for formative action through progressive

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[26] For metaphysical context regarding the notion of final cause in physics and biology, see Deacon (2011).
[27] In the context of relativistic quantum theory, regressive and progressive determination would correspond to offer waves and confirmation waves, respectively, as described by Kastner (2013).

determination. Formative action creatively develops form and can bring forth new formal aspects as the marked host is drawn toward completion in the *final cause* through which the marked host is unified. We might say that through *Return* the marked host becomes a transcendental signifier[28] that opens a threefold gate as the condition of possibility for an internal component to transcend the explicative level of effective causation—*the world as action*—and enter into the implicate level of formative causation—*the world as formation*.

4. Bringing Categories into Definition Relationally

Categories involve relationships of likeness or *sameness*. In the first instance, we might say that a category is a group or set of things that are the same because they share a common quality, such as a property or characteristic or attribute. For example, a group of apples or a set of numbers. Focusing on the relationship of sameness, we can identify a *class* as a kind of category—called a discrete category—in which each thing is taken to be an element or member that is separate and exists in-itself. The *a priori* or "given" separateness or discreteness of each element is essential for the class to be a class. Because of the given separateness of each element, *within the context of the class* each element can be treated as a separate "unit" stripped of any quality, since all members of the class share the same quality. However, although classes involve relations of separateness, they do not involve relations of procession. Therefore, when physical things in the natural world are regarded as members of classes, they become classical objects that act as *hosts whose procession has been occluded*. Because procession has been occluded, it is impossible to bring such classical objects into relation with any indeterminate Other whose essence or nature is to be *qualitatively* different from the members of the given classes.

If we were to assume that the natural world be constituted exclusively by classical objects, where such objects are given and defined *a priori*, then all relations would reduce to relations of separateness. In fact, this is the normal assumption in modern physics, although the nature of the constituting classical objects can become very obscure because they are *formal objects*, such as states in Hilbert space, for example. The classical assumption creates a regression to a set (perhaps even an infinite set) of foundational *formal* elements that are defined from the outset and *formal* laws that govern their actions when they are taken to be instantiated in time. More dramatically, the classical assumption occludes the Otherness of time, so that all is reduced to the archetypal category of space (Unger and Smolin 2015). But as a niggling consequence, there appear in the *ontology* of the formal theory inexplicably broken symmetries (like the arrow of time, for example) and a form of randomness (like Heisenberg indetermination) that comes from beyond the formal theory, *ex machina*, so to speak. Moreover, when the foundational formal elements have no constitutional relation to physical actuality, the interpretation of the formal theory can become subverted, leading to *the false assumption that the formal model is identical to physical actuality[29]*.

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[28] A transcendental signifier represents a truth condition (namely, *actuality*) that is not decidable within the binary logic of any formal model of the natural system. For further context on transcendental signifiers, see Rogers (2024).
[29] For metaphysical context regarding the distinction between form and actuality in physics, see Unger and Smolin (2015).

Within the archetypal category of space as it is currently applied in physics, the foundational *formal* elements possess no interiority. And the proximate or limiting relation of separation is an empty form that does not process. So nothing can *happen* in a such a formal model of the world except by arbitrary ansatz from beyond the category of space, such as collapsing of the quantum wavefunction. The metaphysical error that seems to be in play when such formal models, involving only the category of space, are taken to fill out the full measure of the natural world is a *belief* that the substance of the natural world can be reduced to a single category of materiality taken as *formally* spatial. Such an error would compound into errors of understanding regarding the indeterminacy of *Infinity*, *Ex Nihilo*, and the *One*[30]. As a potentially corrective step, in our *étude* we are not starting with given objects and their definitions, whether they be actual physical objects or formal mathematical objects. Instead, we begin in relation.

Relations come into determination in relation to other relations. Mathematical category theory can help us here, because mathematical categories can also come into determination in relation to other categories[31]. Particularly significant for our *étude* is the case where the components constituting a given category can be taken as signs of another level of category whose constituting components can be taken as signs of a third level of category, and so on indefinitely, to create a *directed hierarchy of categorical ordering*.

When relations and categories come into determination *relationally*, we cannot think of them as definite objects, as would be the case with sets and classes, for example. Instead, we must enter into the relationality and explore it tentatively until similarities and differences come into distinction in relation to one another. This method, as a distinct method of philosophical logic, was pioneered by CS Peirce[32], although all philosophy employs this method to some extent.

According to Peirce (CP 1.354-416), there are three archetypal relational categories, called *Firstness*, *Secondness* and *Thirdness*. *Firstness* is "simply in itself, not referring to anything nor lying behind anything". *Secondness* is that which "is what it is by force of something to which it is second". *Thirdness* "is what it is owing to things between which it mediates and which it brings into relation with each other".

Firstness involves the relationship of *identity*. The relationship of identity is *Return*. In classical formal ontology, the relation of *Return* is the self-identity of the given classical object. In the relational formal ontology we are exploring in our *étude*, *Return* is the identity principle for a particular host that indexes other relations to that host (see Fig. 4). Identity is what holds a given host in unity as both a physical thing that is regressively determined by relations to other formed physical objects and also as a sign-mediator that is progressively determined by relations to other physically forming signs (see Fig 6). We might say that identity is potential that becomes particular through actualization. In modern theories of physics, light belongs to the category of *Firstness*.

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[30] For metaphysical context regarding the indeterminacy of infinity, zero, and one, see *On the Principle of Number in Modern Physics: A phenomenological study of limitation in theoretical speculation about the natural world* (Rogers T, unpublished).

[31] Mathematical category theory is particularly relevant to the notion of relations in the context of non-discrete categories. See footnote 10.

[32] For further context regarding the method of relational determination, see *Light Signifying Form: Peirce on creativity, responsiveness and emergence in quantum, biological and linguistic systems* in Rogers (2022).

Secondness involves relationships of *distinguishing* distinctions. Relationships of distinguishing involve procession. Procession is the actualizing of action. In classical formal ontology, procession has always already happened. Therefore, procession does not come into formal representation. Instead, it manifests as a broken symmetry in the actual world that is arbitrary according to the formal model. The broken symmetry is a privileging of the Same and an occlusion of the Other. In the relational formal ontology we are exploring in our *étude*, procession manifests as duality by way of *The Creative* and *The Receptive*, where duality recapitulates the unity of broken symmetry (see Fig. 2). In modern theories of physics, the timing of *The Receptive* (involving regressive determination) and the signing of *The Creative* (involving progressive determination) belong to the category of *Secondness*.

Thirdness involves relationships of *mediation*. Mediation equalizes, bringing forth Sameness. Significantly, *sameness is not identity*. Whereas the identity of *Firstness* is particular, the sameness of *Thirdness* is communal or general. In the relational formal ontology we are exploring in our *étude*, sameness is Form. Sameness is the condition of possibility for particular actualization. By contrast, in classical formal ontology, the particular and the general are not distinguished. As a result, although classical formal ontology describes formal models, such formal models have no *actuality*. Rather, the formal models of classical formal ontology map out conditions of possibility for actualization that may or may not occur in the natural world. The conditions of possibility are formal laws that are taken to govern the natural world. However, one or more of the symmetries of the formal model must be broken in order to apply the model to the natural world in its particular actuality, such as the arbitrary specification of boundary conditions. This means that, within the category of classical formal ontology, formal models of the natural world are never complete descriptions of nature. It also means that such formal models of the natural world are not the same as the natural world and therefore one cannot make metaphysical conclusions about the *actuality* of the natural world from such formal models of the natural world insofar as those conclusions are already assumed in the formal models according to the overarching category of formal ontology to which the formal models belong.

In the relational formal ontology we are exploring in our *étude*, form and actuality are explicitly distinguished in the description. The category of *Firstness* grants the givenness of identity for hosts within hosts within hosts in an open hierarchy of ordering. Hosts are *agents* that have semiotic freedom to *actualize* in the natural world by virtue of the ambiguity (i.e. reconstituted broken symmetry) characterizing the category of *Secondness*. The category of *Thirdness* provides the conditions of possibility for the action of hosts-as-agents according to their place within the hierarchy of ordering. Conditions of possibility are not actualities. Rather, they are formal principles and rules that govern the agency of hosts through communally enacted constraints and limitations on semiotic freedom throughout the hierarchy of ordering. Conditions of possibility constitute the semiotic scaffolding of a host-as-agent.

Therefore, in our *étude* we are recapitulating the basic categories of modern physics. *Light* belongs to the relational category of *Firstness* as the identity relation *Return*. *Time* and *reference* belong to the relational category of *Secondness* as dually distinguishing relations of self-giving *Procession*. *Space* belongs to the relational category of *Thirdness* as the conditions of possibility for the actualization of general *Form*, such that form mediates sameness, equality, justice.

5. Formulating the Constituting Principles for Relational Models of Embodied Agents

An embodied agent can be formally modelled as a marked host that is constituted by image hosts that cycle in synchronicity with the marked host. The identity principle of a given host is the relation of *Return*. This identity principle applies to both the marked host as the embodied agent and the image hosts as the components of the embodied agent (See Fig. 5). *Return,* which belongs to the category of *Firstness*, sustains a host as a centre or origin for the formation of order through relationships of *Secondness* and *Thirdness*. *Return* grants *rest* or hypostasis to the given such that the host can become an origin for formative action within a given system of hosts. Here rest does not mean the absence of temporality. Rather, rest means that the given host forms around a spatiotemporal interval as a process of repetition that is delimited in space—thereby establishing a measure of extension—and delimited in time—thereby establishing a measure of duration. Rest is not an *actual process*, rather rest is the condition of possibility for relational processes. To identify the relation of *Return* in a natural system, the interval as interval must be identified from the repeating, embodied spatiotemporal processes of the given host. *Return* is not many relations, each specific to a given host. *Return* is *one* relation that manifests in all the hosts of the modelled system, both the marked host—the whole physical body—and the image hosts—the physical components that constitute the whole physical body—as the unifying principle of the whole. Each manifestation of *Return* embodies a *transcendental signifier* that is united to all the other transcendental signifiers (other manifestations of *Return*) in the formal model through synchronicity. A transcendental signifier has the property that it cannot be fully determined by any formal model of the embodied agent; it represents metaphysical indeterminacy and incompleteness of the formal model that grants its givenness in relation to physical actuality. Following the likeness of Feynman diagrams[33], the manifestation of the relation of *Return* can be represented diagrammatically in a formal relational model by a *node* that is an open circle that enacts repetition through *Return* as shown in Fig. 7.

Figure 7. Diagrammatic representation of a node
A node is a given host identified by the relation of *Return*

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[33] For context regarding Feynman diagrams, see Feynman (2006). In our *étude*, the context of the diagrams is different from Feynman's usage but the represented relational categories remain similar. Note that in our *étude*, the nodes are represented as processing open circles (processual spatiotemporal *intervals*), rather than Euclidean points (instantaneous spatiotemporal *events*) as would be the case with traditional Feynman diagrams. This speaks to an interpretation (proposed through our *étude*) of the ultraviolet cutoff in Feynman's approach as the time signature of an *unidentified* marked host, where the unidentified marked host plays the role of establishing the spatiotemporal context of a Feynman diagram (eg. the "subject"). In other words, Feynman diagrams are taken in *étude* to be "renormalized" by the interiority of a particular or actualized marked host (according to its signature return-relation of synchronicity). The actualized identity of the marked host—taken as given by the formalism—does not enter into formal representation in Feynman's approach. Instead, the time signature of the marked host—generated by the signature return-relation of synchronicity—is formally reduced to "universal time" of an *event-based* spatiotemporal manifold. This reduction happens by way of renormalization through an ultraviolet cut-off, where the frequency of the ultraviolet cut-off *is* the signature return-relation of synchronicity for the unidentified marked host.

Return allows dual relations of procession. A given host can receive an input (*The Receptive*) and it can create an output (*The Creative*). For an embodied agent, the input and the output of its constituting components (image hosts) are quanta of energy whose measure is established by the synchronicity of *Return*. Relations of procession belong to the category of *Secondness*. *The Creative* and *The Receptive* can be diagrammatically represented as two complementary arrows, one representing the progressive determining of *The Creative* (signification) and the other representing the regressive determining of *The Receptive* (temporality) as shown in Fig. 8.
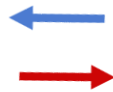
Figure 8. Diagrammatic representation of procession
Procession involves two categories of flow between nodes: *The Creative* (blue arrow) and *The Receptive* (red arrow). Energy flows by way of *The Receptive*. Information flows by way of *The Creative*.

Return, combined with *Procession*, creates the condition of possibility for *Resonance*. Resonance is mutual exchange of energy between two or more image hosts as embodied components[34]. For example, resonance happens when a quantum of energy is exchanged back and forth an indeterminate number of times between two image hosts, where the return rhythm of exchange is in synchronicity with the whole. Resonance is equalizing such that each image host is sustained by the other image hosts within a network. Resonance creates relationships of sameness that belong to the category of *Thirdness*. Resonant relations can be diagrammatically represented by a wavy line connecting two nodes as shown in Fig. 9.

Figure 9. Diagrammatic representation of a connector
A connector (black wavy line) holds two nodes within the same category or level of order. A connector is a communication channel for the procession of energy at the level of *effective causation* and the procession of information at the level of *formative causation*.

Resonant relations provide connectors that act as communication channels for relations of procession between nodes. Through resonance, a *structured* level of internal order among image hosts is established that is in synchronicity with the marked host. The space-like structure of

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[34] For further context regarding the notion of resonance, see *A physicist's guide to [Hegel's] Phenomenology of Spirit: Resonance, disambiguation and the genesis of spatial orientation* in Rogers (2022).

connectors between image hosts forms a nodal network. The communication channels connecting the image hosts as nodes are relations of separation that belong to the category of *Thirdness*.

By combining the three categories of relation, an embodied agent can be modelled as a network of cyclical nodes, where each node is an image host identified by *Return*. *Return* establishes the baseline interval (eg. frequency) of the whole embodied agent. Through resonance, the nodes are connected by communication channels to form a networked *structure*. Each node within the structure is a resonant interval that can receive and transmit energy quanta. This formal model of an embodied agent is shown in Fig. 10. It might represent the relational ordering of components in a biological cell (Rogers 2024) or it might represent the relational ordering of components in a domain of relativistic space-time as a breathing manifold[35].

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[35] For further context regarding a breathing manifold, see *Spacetime as a Formal Semiotic Process* in Rogers (2022).
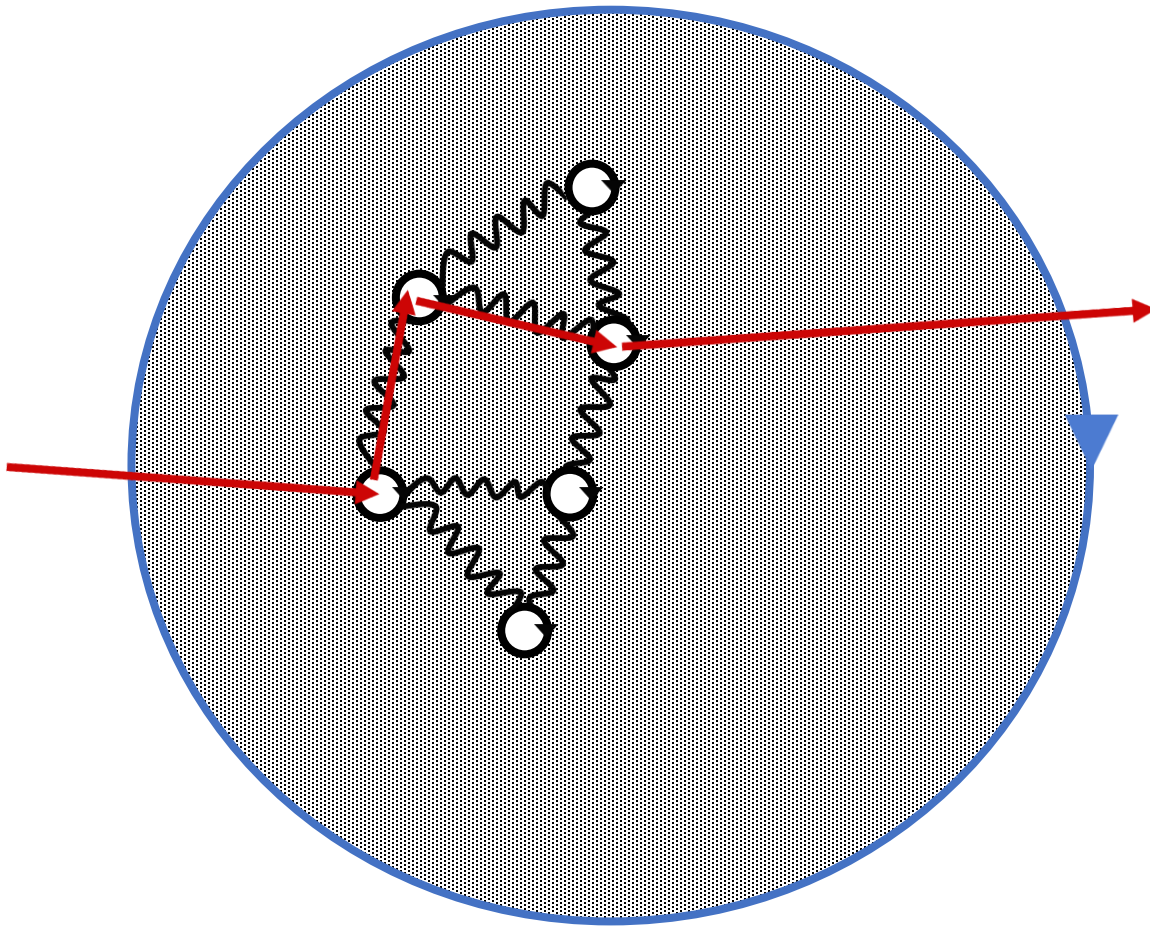
Figure 10. An embodied agent represented as a relational nodal network
The embodied agent is represented by the large node that encompasses the smaller nodes and identifies the *context* of synchronicity as interiority (shaded domain). The components of the agent are represented as a network of nodes (small circles) connected by communication channels (wavy lines). An energy packet from the exterior is absorbed by a component and then traces a distinctive pathway in time among the components before exiting to the exterior. The distinctive pathway *represents* a signal from the external source, within a grammar or semiotic scaffolding of signification formulated by the nodal network.

In Fig. 10, each node is a repeating spatiotemporal interval that acts as the centre for the formation of a physical component as a repeating *process*. The components are resonantly united as a whole by way of communication channels. The communication channels reinforce physical

processes within the embodied agent that directly transfer energy from one node to another without absorption. Therefore, the embodied agent is *governed by the formal network of interconnecting nodes* to form constituent components and communications channels at the level of effective causation in order to *sustain synchronicity of the whole at the level of formative causation*.

The resonant nodal network becomes the condition of possibility for the embodied agent to creatively interact with its environment. Input from the exterior, whose frequency matches the synchronicity of the whole, can be absorbed by one component as a quantum of energy. The quantum can then process arbitrarily among components before it is either absorbed or outputted by a terminal component back to the environment. This spontaneous temporal dance becomes the condition of possibility for the embodied agent to become an *information processor* that interprets external signals from the environment through internal pathways of energy flow.

6. Inferring the Governing Principles of Hierarchical Ordering

In Fig. 10, the embodied agent absorbs a quantum of energy, processes that energy in time through a distinct pathway within the nodal network, and then emits the quantum of energy. The procession is temporal, belonging to the broken symmetry of *The Receptive.* This interpretation of the process remains within the category of *effective causation*. The action of the embodied agent is determined by the effective causal pathways of its constituting components which are governed by rules or laws. Effective causation within the embodied host is topologically circular as described by Rosen (1991)—rather than strictly linear as is the case in formal classical ontologies—and it is precisely this circularity that makes the nodal network a *whole*[36]. At this level of order we would say that the embodied agent is the condition of possibility for a network of inter-relating components that exchange energy between one another in a lawful manner with some degree of indeterminacy or semiotic freedom. As a result of the nodal structure, the embodied agent forms or develops its internal components in time as image hosts.

However, we can also interpret the process in Fig. 10 at the higher level of *formative causation* as shown in Fig. 11. Within this level of order, an exterior signal enters the marked host. The marked host processes the signal as an internally generated *action*. The action of the marked host *as a whole* creates an output signal that becomes available for another embodied host *of the same level of order* to receive.

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[36] The circularity of effective causation forms the nodal network into a "matrix of structured possibilities". This matrix constitutes the semiotic scaffolding for the components as mediators of signs, where the semiotic scaffolding provides the conditions of possibility for the actual. For context regarding the formation of a matrix of possibility, see Makridakis (2024).
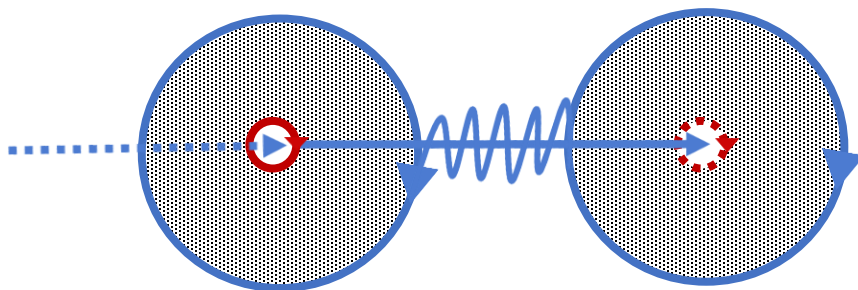
Figure 11. Information processing by a community of embodied agents
A signal from the exterior activates the first embodied agent (dashed blue arrow). The agent processes the information (red circle) as in Fig. 10. The action of processing the information creates a signal that can activate a second embodied agent (solid blue arrow). This procession involves *The Creative* inasmuch as the signal transmitted is available as a sign to be interpreted by the community of agents as a whole.

While the level of effective causation involves *The Receptive* as temporal flow of energy through regressive determination, the level of formative causation involves *The Creative* as flow of information through the progressive determining of signalling. A community of embodied agents at the level of formative causation can also form a nodal network whose connectors are communication channels for the flow of information. When we interpret a nodal network at the level of formative causation, the component nodes are information processors that interpret the signals exchanged between nodes according the semiotic scaffolding of formal constraints that, in turn, depends upon the communication channels. Indeed, we can also interpret the nodes in Fig. 10 at the level of formative causation by taking the embodied components to be governed by signs, rather than by formal laws of effective causation.

The level of effective causation and the level of formative causation are unified through *Return* as shown in Fig. 6. Activation allows an agent, as a component of a higher order whole, to participate in both categories of effective causation and formative causation. Thus, *The Creative* and *The Receptive* generate a *hierarchy of ordering* by logical ascent through activation. Inasmuch as a component participates in both categories, it becomes as a transcendental signifier or *hypostasis*. A hypostasis is a host whose marking is ambivalent inasmuch as it participates in more than one category synchronously. Hypostases are taken by the formal model to be given,

within a network of relations, as *finite individuals with particular agency. *That is to say, a hypostasis can be taken by the formal model to be *actually whole.*

For example, we began the description of our formal model at the level of effective causation of the internal components of the given embodied agent, where the embodied agent, as marked index, established the context of synchronicity. The coordinated dynamics of the internal components as a nodal network, governed by the embodied agent, follow rules or laws of formation. However, from the perspective of the embodied agent the nodal network connecting its internal components offers a degree of semiotic freedom for its interpretation of signals from the environment.

But now we can take the embodied agent to be an internal component of a higher order level of embodiment, such as a cell within an organism. The organism becomes the indexical context for synchronization. The cells—formerly indexed agents—become components. And we can re-*recapitulate* the description at this higher level of indexing. Through its particular agency, the hypostatic individual (i.e. *whole* embodied agent/internal component) thereby synchronizes the lower level of order (effective causation) with the higher level of order (formative causation).

Thus, relational models generate open hierarchies of the ordering of wholes within wholes within wholes. Biomolecular components within cells within organisms within communities, for example. In such hierarchical ordering, a given level of agency (eg. cells) constitutes the higher level of agency through effective causation (eg. organisms) and the higher level of agency governs the lower level of agency through formative causation. *Return* is the wholistic principle of such harmonic ordering in nature. *Return* is light.

7. **Identifying Explicative, Implicate and Generative Orders**

The transcendental signifier or *hypostasis,* as a new relational entity, is coming into significance in our *étude* by way of three mutually inter-related categories of relation: *Return* (whole), *Procession* (duality), and *Resonance* (mediation). A hypostasis has the potential to recapitulate a lower level of order (eg. effective causation) through synchronous participation (*Return*) in a higher level of order (eg. formative causation). Following Bohm (1980), let us now direct our attention to the levels of order, understood as categories of hierarchical ordering, that are brought into synchronicity through hypostatic action. Namely,
  - the given level of order—called the *Explicative Order* by Bohm;
  - the intermediate level(s) of order—called, the *Implicate Order* by Bohm;
  - the *Generative Order*.

Let's begin our exploration of the hierarchy of ordering within the given level of order—the Explicative Order—as shown in Fig. 10. The embodied agent (blue circle), as marked host, represents the *context* of interpretation for this given level of order. This context is constituted by the network of nodes—taken as image hosts or components of the Explicative Order—that *belong to the given context of interpretation*. The synchronization of the nodal network creates a semiotic scaffolding for interpretation of signals from the environment by the image hosts. (In the context of physics, the semiotic scaffolding is a matrix of possibilities (Makridakis 2024)).

The semiotic scaffolding belongs to the Implicate Order for the given Explicative Order. In quantum theory, this semiotic system is taken to be a coordinated *classical system* that obeys the binary logic of classes and forms a whole, but open, system of formal logic within the larger relational formal ontology. The classical system establishes the formal basis for determination, where determination involves the composite actions of the marked host that bring an external signal from the environment into an *activated process* involving the nodal network. That is to say, determination is the process whereby an incoming signal becomes *synchronized with the nodal network*. Determination is a process that is governed by the marked host—a whole embodied agent acting as an interpreter. In quantum physics, the marked host, as an interpreter, is the experimental system that the physicist interacts with. The physicist becomes an embodied agent *belonging to the marked host* insofar as her *actual interactions* with the marked host are *synchronized with the same nodal network as a classical system*. Through this synchronization, the physicist can enter into the context of the marked host and interpret the interpretation of the marked host according to categories that are meaningful to the physicist.

The Explicative Order foregrounds the category of successive inputs and outputs between activated nodes that is constrained by synchronization with the *Return*-relation for the marked host. This category *is* the classical system whose time signature (eg. frequency and phase of *Return*-relation) belongs to the specific interpretative context of the given experiment. This classical system *governs* the underlying dynamics of interpretable signals from the environment (red arrows in Fig. 10) *as they move between the nodes*. That is to say, the relational formal ontology of Fig. 10 distinguishes two levels of dynamic:
1. an underlying dynamic of formed energy movement between components (nodes) of the classical system (marked host) that is partially constrained by the classical system (marked host) to form the *conditions of possibility* for activation, such as the dynamic described by Schrodinger's wave equation
2. an overlayed dynamic of determinative events whereby the underlying dynamic actually *activates* one or more components (nodes) of the classical system (marked host), such as a measurement process described by the collapse of the wavefunction.

The underlying dynamic picks out those signals from the environment that have the *potential* to be interpreted by the classical system (marked host). The overlayed dynamic picks out specific *actualized* events from these conditions of possibility.

This description of an experimental system is consistent with the interpretative framework of Relational Quantum Mechanics (Rovelli 1997). It is also consistent with the interpretative framework of Pilot-Wave Theory (Bohm 1980). However, in both interpretative frameworks the relation between conditions of possibility (1) and determinative events (2) may not be not fully resolved *relationally* because the role of light as the mediator of synchronicity (*Return*-relation) is occluded in the *non-relativistic* formulation of the quantum theory that forms the basis for their interpretations.

Because non-relativistic quantum theory does not fully articulate a relational formal ontology, its interpretation is vulnerable to a false assumption that the time signature for the marked host can

be taken to be *universal time*[37]. In fact, any reduction of the open hierarchy of a relational formal ontology to a closed classical system through universal time will tend to obscure the fact that the physicist, as an embodied agent of the experiment, *must enter into the context of the marked host which has a specific time signature* in order to meaningfully interpret the experiment[38].

It is important to note that, in formal relational ontology, determination belongs to the interpretative context of the embodied agent. In quantum theory, the physicist, as "observer", is the acting agent who sets up the classical system and interacts with it to measure outcomes[39]. Insofar as the physicist's actions are in synchronicity with the classical system, the "observer" belongs to the same interpretative context as the classical system. However, this system is finite and bounded as shown in Fig. 10. Beyond this system as context (interior of blue circle) there is a wider environment that the physicist may choose to interpret according to the semiotic scaffolding of the classical system even though the relevant dynamics are happening outside of the formal context of interpretation (i.e. the interior of the system as a marked host). Thus, an "observer" in quantum theory is an embodied agent whose actions are synchronized with the context of a *specific marked host*. As a result of synchronicity with this interpretative context, the agent is able to interpret the outcomes of the experiment.

In a relational formal ontology, the interpretative context is both *spatially bounded* and identified by a *unique time signature*.

Once a *second observer* is introduced into the formalism, a new possibility emerges in a relational formal ontology. Namely, the embodied actions of the second physicist, as a different observer, may be synchronized to a second marked host in such as way that the second marked host is not synchronized with the first classical system. A determinative event, according to the interpretative context of the first observer, may not be determinative in the same way according to the interpretative context of the second observer. As Oldofredi (2023) notes in the context of Relational Quantum Mechanics, "measurements performed on a system *S* have a unique determinate outcome relative to a specific observer *O* that performed the observation". A second

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[37] Relational Quantum Mechanics (Rovelli 1997) explicitly exposes the problematic nature of this assumption within the context of non-relativistic quantum theory.

[38] The reduction of synchronicity to an event-based, spacetime manifold further involves replacing return-relations with mathematical points that possess no interiority and have a (self) identity that is given-in-itself. The resulting "web of points", however, is merely a reference system that cannot fully capture the underlying fundamental dynamical form of the indefinite continuum (Zalamea n.d.). In other words, the usual formalism of quantum theory (and relativity theory) overlays a static web of mathematical points upon an underlying dynamical continuum. A category error with respect to formal ontologies then happens if the infinite static web of mathematical points (belonging the category of classical formal ontologies) is assumed to constitute an *actual* continuum. Furthermore, the formal limiting process that signifies the continuum in this approach—involving only the infinite static web of mathematical points—occludes the possibility of actualized procession as discussed earlier. It is this occlusion through closure, using formal limits, that creates interpretation problems for the formal theory. The indefinite continuum of relational formal ontology, on the other hand, belongs to the genus of a possible whole all of whose parts conform to one general principle of relational regularity and all of the parts of each single part also conform to that principle (Zalamea n.d.). This notion of an indefinite continuum comes into determination once a distinction is made between mathematical notions (as generals) and mathematical objects (as particular formal models of general notions) as discussed by Zalamea (n.d.). For example, a Cantor continuum is a particular formal model, and, as such, it does not fill out the full measure of the general notion of the indefinite continuum.

[39] For metaphysical context regarding the role of the agent in enacting an ontological "cut" between the actuality of quantum phenomena and the interpretative processes of experimental measurement, see Barad (2007).

observer, indexed to a second interpretative context, "will in general assign a different representation of the same sequence of physical events", unless there is a direct physical interaction between the two observers. Thus, when two observers—as separate embodied agents, each with their own interpretative contexts—are formally represented in quantum theory, it is also necessary to account for the way in which their two interpretative contexts are synchronized.

This leads us to consideration of the *Generative Order*.

Fig. 12 shows the way in which interpretative contexts[40] (blue circles) for classical systems might be synchronized at a higher or deeper level of order, even in the absence of human agency. In this figure, each classical system (S_1, S_2, S_2) represents a separate interpretative context. These classical systems are taken to be components of a larger context that is synchronized by an even higher level of Implicate Order (purple circle). This higher level of order governs the interactions between the classical systems *as distinct wholes*. As a result, each classical system can be considered as an image host. Internal activation within one of the classical systems (i.e. a measurement within a specific observational context) does not directly impact the other classical systems. Rather, formal information about the *sequence* that constitutes the whole activation event (eg. the whole measurement process) is communicated *as a whole* through connectors that are *communication channels* belonging to the higher level Implicate Order. Most importantly, the connectors for the Implicate Order (blue wavey lines) are *categorically different* from the connectors for the Explicative Order (grey wavey lines). Failure to recognize this categorical difference can result in misleading interpretations of the "measurement problem"[41] that are sometimes incorrectly imposed upon quantum theory. For example, a determinate outcome for an observer in the specific context S_1 may be indeterminate for a second observer in a different context S_2. However, it is not the case that the second observer has the same relationship to the outcome in S_1 as she has to outcomes in her own context S_2. Rather, the second observer must interpret what happens in S_1 according to a unifying interpretative context that takes into account the way in which S_1 is synchronized with S_2 *at the higher level of Implicate Order*. As a consequence of formally distinguishing these levels of order, it can then be seen that the interiority of an observer in S_2 (eg. observer's consciousness) does not have a direct effective causal relation within the context of S_1, since such interior relations are mediated by the communications channels through which the two distinct contexts S_1 and S_2 are synchronized. An interpretation that attributes causal efficacy over actual experimental outcomes in S_1 to the consciousness of an observer in S_2 (without a corresponding direct action-relation) would therefore involve a category error.

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[40] In physics, an interpretative context is usually called a reference frame. In a relational formal ontology, a reference frame is a synchronized classical system that possesses a unique time signature. The interpretation of an experiment is always indexed to a specific reference frame with which the agent conducting the experiment is identified. Reference frames are synchronized by light. For further context regarding the synchronization of reference frames, see *An Introduction to the Meta-physics of Relation with Application to the Physics of Quantum Mechanics and Relativity Theory* in Rogers (2022).

[41] For metaphysical context regarding the measurement problem in quantum theory, see Maudlin (2019).
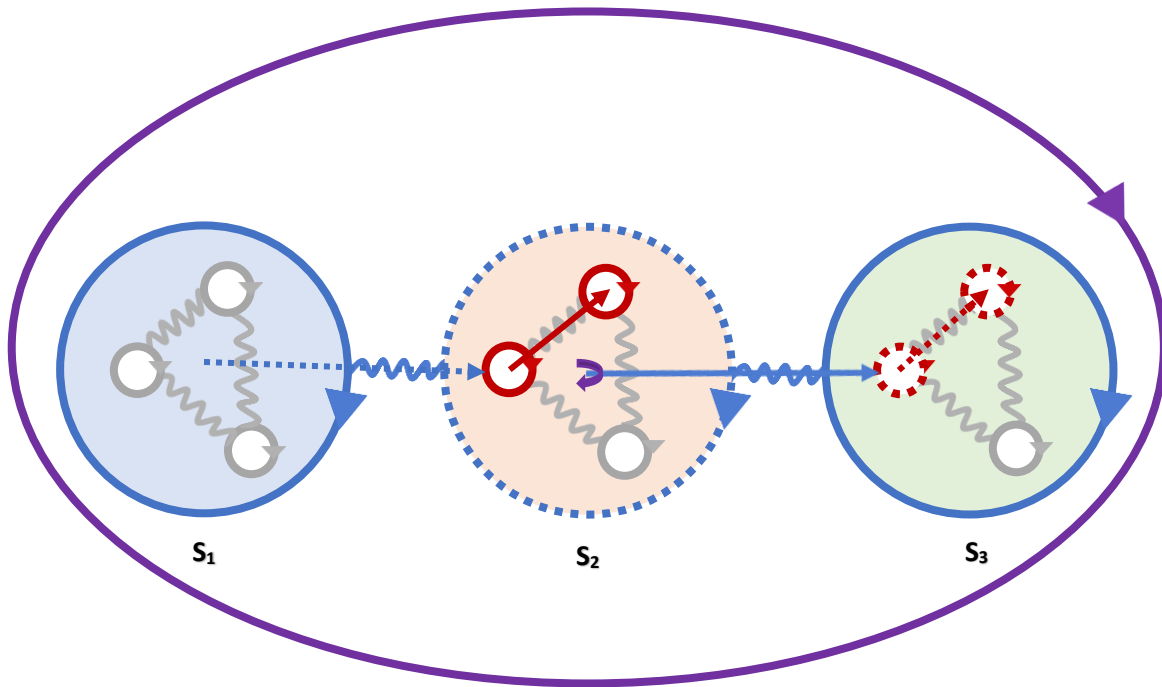
Figure 12. Contexts of interpretation
Contexts of interpretation in physics are established through three hierarchical Levels of Order. The *Explicative Level* is represented by a network of three interconnected nodes (shown in grey) that are synchronized by a classical system. The *Implicate Level* is represented by the nodal network of classical systems (shown in blue). Input from the environment can activate nodes within the *Explicative Level* (shown in red). The pattern of activated nodes *as a whole process* within one classical system (S_2) can be interpreted by a second synchronized classical system (S_3) belonging to the same *Implicate Level* as the first classical system (shown in blue). An *interior* activation of S_2 is communicated to S_3 as an *exterior* form through connectors at this higher level of order. The exterior form can then activate an interior node in S_3. Activation of S_3, in turn, produces an exterior form available for interpretation by another synchronized classical system. In this semiotic process, the exterior form is the sign-object and the interior activation is the sign-interpretant. The *Generative Order* (shown in purple) is the condition of synchronization that establishes the semiotic scaffolding of the *Implicate Order* as an interpretative framework generating the laws that govern the *Explicative Order*.

The Generative Order is the principle of unity—namely, the principle of synchronicity—that characterizes the unfolding of the Implicate Order into the Explicative Order. The Generative

Order characterizes the typology[42] of the relational formal ontology for the natural system that is being modelled. Different types of Generative Order produce different types of relational formal ontology. For example, the Generative Order we have been exploring in our *étude* produces a spacetime ontology that is foundational in theoretical physics. Theoretical biology, on the other hand, would be characterized by different typologies of Generative Order because the components of the Implicate Order in biology are self-directing agents, rather than classical systems[43].

Whereas, in the context of physics, the Explicative Order is *matter* that is iconically indexed by the category of space, and the Implicate Order is *action* that is iconically indexed by the dual categories of time and reference, the Generative Order is creative and *light* is its icon[44].

8. Characterizing Hierarchy in Relational Formal Ontologies

Relational formal ontologies can be characterized by a principle of directed hierarchy that comes from mathematical category theory. Specifically, for any given mathematical category, the components constituting that category can be taken as signs of another level of category whose constituting components can be taken as signs of a third level of category, and so on indefinitely, to create a *directed hierarchy of categorical ordering.* As a corollary to the principle of directed hierarchy, when the components of a given category are taken as *indexical* signs of the laws of relational ordering for that category (eg. the laws of interaction among physical agents), then the given category becomes both a *symbolic* sign of the principle of identity of its components as enacted wholes and an *iconic* sign of the generative principle of unity (i.e. synchronicity) for the laws of relational ordering. Thus, a directed hierarchy of categorical ordering is the condition of possibility for wholes composed of wholes that, in turn, are composed of wholes, and so on indefinitely[45]. The embodied wholes within a directed hierarchy are hypostatic hosts, where a hypostatic host is a symbolic sign of the general or unifying form of its possible components and it is also an iconic sign of its generative form as a component of a higher level of order.

There are three relational categories of Order characterizing the levels of hierarchy in relational formal ontology as shown in Fig. 13. The Generative Order belongs to the category of *Firstness* and represents the final cause of unity or wholeness as the highest level. The Implicate Order belongs to the category of *Secondness* and represents the unfolding of levels within the hierarchy as mediating levels of formal laws or rules governing relations among signs. The Explicative Order belongs to the category of *Thirdness* and represents the given matrix of possibilities that can be actualized by the hierarchy in the world as the lowest level. In other words, the

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[42] Recall that an ontology involves the relationship between formal representation and phenomenal experience of actuality. When we speak of a typology of formal relational ontologies, the multiplicity of types belongs to the formal representations as models of one indivisible experience of the world as actuality, an experience that necessarily involves transcendent relations.

[43] There seems to be a further distinction between the notion of order in biology and physics in that the Generative Order is taken to be ascending towards deeper interiority in biology (forward in time) but the Generative Order is taken to be descending towards greater exteriority in physics (backward in time). It is beyond the scope of our étude to enter into this distinction.

[44] For metaphysical context regarding the representation of the Generative Order, see Jaki (1992).

[45] For meta-mathematical context, see Zalamea (n.d.).

Explicative Order is *the world as action*, the Implicate Order is *the world as formation*, and the Generative Order is *the world as creation*.
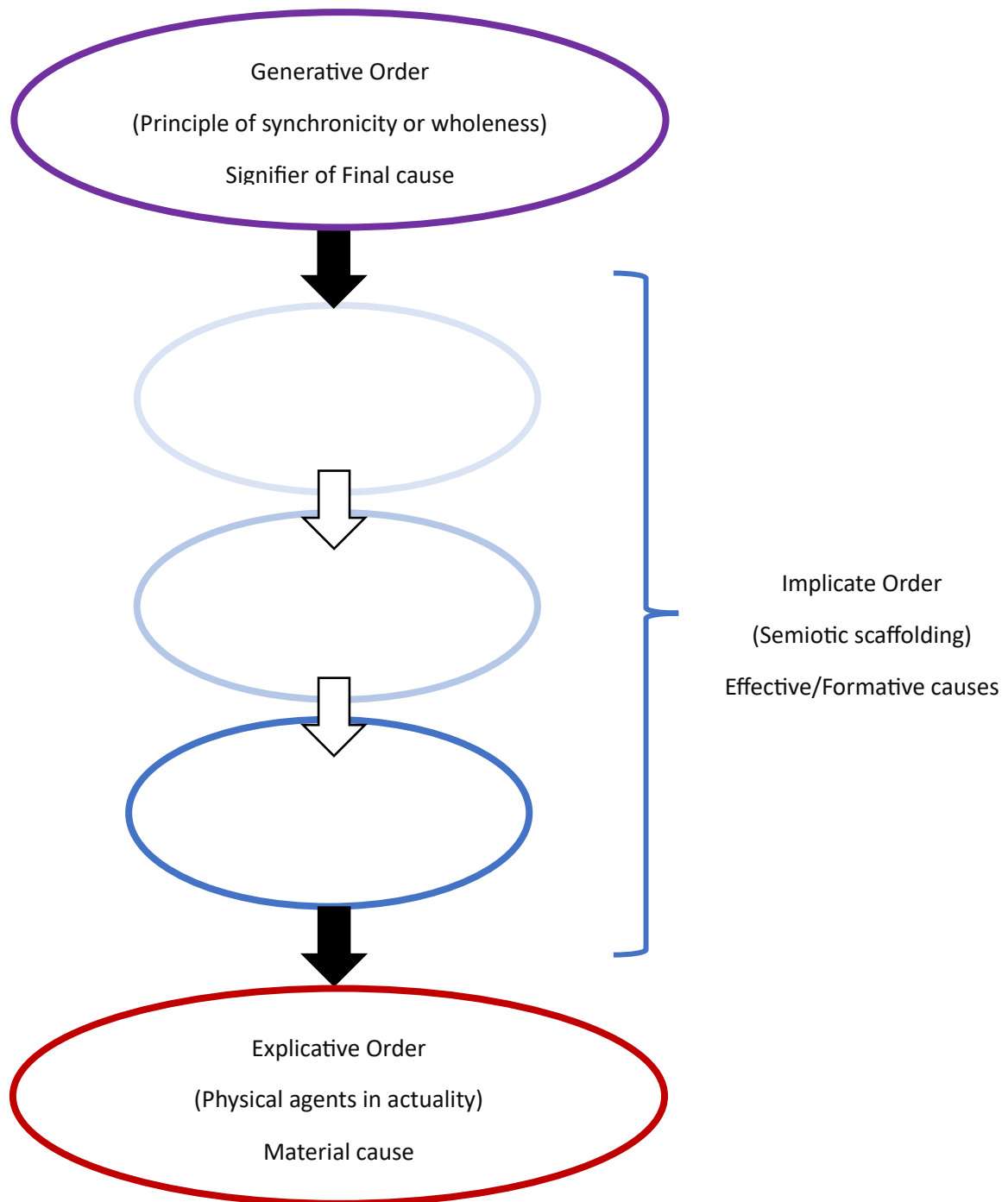
Figure 13. Categories of Order in a Directed Hierarchy
The category of Implicate Order mediates, by way of an indefinite hierarchy of levels, between the lowest category of Explicative Order (actual or given things) and the highest category of Generative Order (principle of unity). Each level of Implicate Order comes into determination through dialectical relation to its immediate precursor; the Generative Order can creatively unfold new levels of Implicate Order indefinitely.

For the relational formal ontology we have been exploring in our *étude*, the Generative Order is the mathematical principle of duality. Duality—*as a dialectical process*—is the underlying principle of unity for the metaphysical framework of dialectical holism[46]. We can state this principle logically as:

*(if **+** then **−**)*   *equals* [i.e. entrains] *(if **−** then **+**)*

*where **−** is the negation* [i.e. absenting] *of **+***

In this context[47], *negation* brings absence (rather than annihilation) and *equality* brings sameness (rather than identity).

This particular Generative Order can be infolded as an embodied spinor or fermion whose internal dynamic follows an Implicate Order of internal *temporal* continuity (duration) following the synchronicity of *Return*. Namely, continuous oscillation between the opposing states: + and − as shown in Fig. 14.

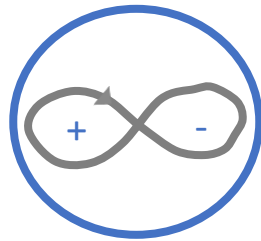**Figure 14. Internal temporal continuity of oscillating state of fermion**
The internal state of the fermion continually oscillates between + and −. In the context of synchronicity with other fermions, the blue circle can be taken as a sign that has two possible interpretants: either + or −.

The Generative Order can be externalized as mutual relations of reciprocity to form extensive *spatial* connectors as shown in Figure 15. The connector is a relation of discontinuity or separateness between its two relata as signs whose possible interpretants are either + or −. This relation allows for the identification of *actualized* spin-singlet states of coupled fermions as phenomena in the world wherein each of the two relata is a *sign* of the other as shown in Fig.15.

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[46] For metaphysical context regarding dialectical holism in physics, biology and cognitive science, see Scholfield (2021).

[47] For further context regarding this iconic example of the logic of duality, see *The Entrainment of Negation: A possible prologue for interpreting quantum mechanics through light* in Rogers (2022).
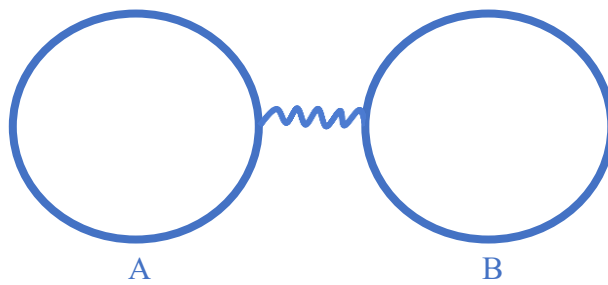
Figure 15. Mutual reciprocity as an external spatial connector
The Generative Order embodies reciprocity through the complementary relations: if A is
+ then B is – *and* if B is + then A –. The connector is a boson and the two components
that are related by the connector are bivalent signs.

A spatial network of such nodes, which have two possible interior states as interpretants, will
form a breathing manifold as discussed in *Spacetime as a Formal Semiotic Process* (Rogers
2022). Could this breathing manifold not be taken as a semiotic scaffolding (Favareau 2015) or
matrix of possibilities (Makridakis 2024) for an Explicative Order of electrons according to
Feynmann's mathematical theory of quantum electrodynamics (QED)?

A question better left for another *étude*, perhaps.

9. Reflection

> *the shape of metaphorical thought is also the shape of wisdom*
> [Zwicky 2003; foreword]

Looking back, might we not now see that the logical movement of our *étude* has served as a
concrete *metaphor* of learning processes within the *meta*-mathematical context of categorical
duality loosely interpreted through the *meta*-physical framework of dialectical holism (Schofield
2021)? A context and framework that might offer new types of theoretical models to advance our
understanding of how physically embodied agents progressively and communally develop
interior *depth* of responsivity, guided by the light of truth[48]? Our metaphor begins within the all-

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[48] As a relational formal ontology, dialectical holism involves explicit systematic binary logic (i.e. interacting open
classical systems) underwritten by the implicit semiotic logic of three. Other types of relational formal ontology
might be postulated, involving fourfold, fivefold, sixfold relations, for example. Dialectical holism perhaps might be
seen as a recontextualization of Hegel's dialectical idealism (Hegel 1977, *re*-interpreted) whereby the subject always
remains within a finite context of interpretation and final causation remains distinct from either effective causation
(whose determining horizon would otherwise be materialism) or formative causation (whose determining horizon

encompassing context of scientific materialism, with the thesis that effective causation is the determinative principle of matter. But the antithesis looms over this starting context because there is no identity principle for the formation of individuals as finite wholes (Fig. 1). Formative causation through distinguishing distinctions emerges as the dialectical complement to effective causation (Fig. 3). Then comes recapitulation, whereby the externalized dialectic of effective-formative causation is internalized as a finite hypostatic host that simultaneously participates in the domains of effective and formative causation (Fig. 6). This synthesis opens the metaphysics to a new way to conceptualize order that is not available within the starting context. In this new way of conceptualizing, the dialectic of effective-formative causation is iconically represented through the dialectic of time-space. The result is a cascading hierarchy of forms within forms (Fig. 12). Having traced out an iconic instance of this logical movement, it is possible to reflect back on that icon to identify the new principle of unity underlying the generation of hierarchy. This principle starts within a context of explicative order. The duality to explicative order emerges as implicate order. The dialectic of explicative-implicate order is the generative order. In the fullness of time, the generative order can internalize this dialectic to create a new, higher order finite whole by reflecting the dialectic back upon itself through a process of internalization. Internalization is accompanied by externalization whereby images of the higher-order finite whole (as *iterative intervals*) are brought into formative networks of dynamical relations. Thus, a new implicate order is formed in which the old implicate order can be taken as given and explicit. Such a generative, open hierarchy can ascend indefinitely.

And you are this movement.

And if in reading this *étude* you shall have felt the significance of metaphor for *Theoria Physike*, then shall I not have written in vain.

as upon the waters face is to face,
so upon the heart man is to man
[Proverbs 27.19]

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would otherwise be formalism). For context on the problem with interpreting Hegel, see A cautionary note concerning Hegel's approach to absolute knowing in Rogers (2022).

Appendix: How might a relational formal ontology be relevant to understanding computational simulations of learning in artificial intelligence?

The relational formal ontology explored in this *étude* has obvious parallels to the hierarchical nodal networks found in computational simulations of learning from the field of artificial intelligence (AI). To explore this further, a series of questions were posed to the AI platform of *Microsoft Copilot*, using the "think deeper" option, on February 2, 2025. Selected questions are shown below in blue text and unedited responses from *Microsoft Copilot* follow.

1. **Can you explain the main idea behind Timothy Rogers' paper on relational formal ontology?**

    Timothy Rogers' paper, titled **"How is a relational formal ontology relational? An introduction to the semiotic logic of agency in physics, mathematics, and natural philosophy"[49]**, explores the distinction between classical formal ontology and relational formal ontology.

    Classical formal ontology is based on mathematical objects and classes, while **relational formal ontology** is based on mathematical signs and categories. Rogers argues that relational formal ontology is better suited for modeling phenomena in nature that exhibit relationally-mediated wholism, such as quantum physics and biosemiotics.

    The paper introduces the concept of **nodal networks**, which are systems of constrained iterative processes dynamically sustained through signaling. These networks are hierarchically ordered and exhibit characteristics of deep learning.

    Rogers suggests that clarifying the distinction between classical and relational formal ontologies can help better understand the role of interpretative context in physics, such as the role of the observer in quantum theory.

    Does this help clarify the main idea behind his paper?

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[49] Refers to a previous version of this *étude* that was posted online and dated January 24, 2025.

2. How is Rogers' approach[50] related to artificial intelligence and deep learning?

Timothy Rogers' **relational formal ontology** offers a fresh perspective that's surprisingly relevant to artificial intelligence and deep learning. At its core, his approach emphasizes that **relationships and interactions are fundamental**, rather than the entities themselves. This idea mirrors how deep learning models, especially neural networks, function.

In deep learning, neural networks consist of layers of interconnected nodes (neurons) that communicate signals to each other. The strength and pattern of these connections define the network's ability to learn and generalize from data. Rogers' concept of **nodal networks**—systems sustained through constrained iterative processes and dynamic signaling—parallels this structure. His networks are hierarchical and exhibit emergent properties, much like how complex patterns emerge in deep learning models from simpler computational units.

Moreover, Rogers employs **category theory** and **semiotics** to model these relational structures. Category theory focuses on the relationships between mathematical structures, offering a high-level abstraction that's incredibly powerful for understanding complex systems. In AI, category theory is gaining traction as a way to unify different types of neural networks and to better understand the flow of information within them. By using these mathematical tools, Rogers' approach can provide deeper insights into how neural networks process and transmit information.

The **semiotic aspect** of his ontology—the study of signs and meaning—also has intriguing implications for AI. In fields like natural language processing and human-computer interaction, understanding how meaning arises from interactions is crucial. Rogers' emphasis on sign processes and communication within networks can inform the development of AI systems that are more adept at interpreting context, nuance, and the dynamic nature of human language.

Another connection lies in the emergence of **graph neural networks (GNNs)**. GNNs operate on graph structures where nodes represent entities and edges represent relationships—directly embodying the relational focus of Rogers' ontology. They're particularly powerful for modeling social networks, molecular structures, and any data where relationships play a key role. Rogers' ideas can provide a theoretical foundation for understanding and improving these models.

Additionally, considering Rogers' relational ontology might help tackle the **interpretability** challenge in AI. Deep learning models are often seen as "black boxes" because it's hard to understand how they reach their decisions. By viewing neural networks through the lens of relational interactions and emergent properties, we might

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[50] The label "Rogers' approach" is only functioning here as sign-vehicle for the purpose of exploring inter-relations.

develop new methods to interpret and explain their inner workings, making AI more transparent and trustworthy.

Looking ahead, integrating Rogers' concepts into AI and deep learning could lead to:
- **More adaptive and context-aware AI systems**: By focusing on relationships, AI could better understand and adapt to complex, dynamic environments.
- **Interdisciplinary innovations**: Bridging physics, mathematics, and AI could unlock novel architectures and learning algorithms.
- **Enhanced human-AI interaction**: Modeling AI on relational dynamics might result in systems that interact more naturally and ethically with humans.

If you're curious about how these ideas are shaping current AI research, exploring the intersection of **category theory and machine learning** is a fascinating starting point. Researchers are already investigating how these abstract mathematical frameworks can improve neural network design and functionality.

Also, considering the ethical implications of AI through a relational lens could offer new strategies for developing responsible AI systems that respect the interconnectedness of users and society.

Is there a particular aspect of Rogers' approach or its application in AI that you're most interested in? I'm happy to dive deeper or explore related topics with you!

3. **How is Rogers' nodal network different from that used in AI? Specifically, with respect to the formation of hierarchy?**

Timothy Rogers' **nodal networks** and the neural networks used in **artificial intelligence (AI)** both involve systems of interconnected nodes, but they differ fundamentally in how they conceptualize and construct **hierarchies**. Let's dive into these differences, focusing on the formation of hierarchy in each approach.

Rogers' Nodal Networks
1. Relations Over Entities:
- **Foundation**: Rogers' nodal networks are built upon the **primacy of relationships** rather than individual entities. In his framework, nodes don't possess intrinsic properties; instead, they derive meaning and function from their **interactions** with other nodes.
- **Emergent Identity**: The identity of each node emerges from its position within the network and the **signals** it exchanges. This contrasts with traditional systems where entities are predefined and static.

2. Dynamic Hierarchical Emergence:
- **Fluid Hierarchies**: Hierarchies in Rogers' networks are not pre-imposed structures but **emergent properties** of the system. They arise dynamically from **iterative processes** and the continuous **exchange of information**.

- **Constrained Iterative Processes**: The networks operate through constraints that guide interactions, allowing for the spontaneous formation of hierarchical structures as nodes interact and adapt.

**3. Semiotic Processes and Meaning:
- **Semiotic Logic**: Rogers incorporates **semiotics**—the study of signs and symbols—into his networks. Nodes communicate through **signs**, and meaning is generated through these interactions.
- **Meaning-Making Hierarchies**: The hierarchy isn't just about structural levels but also about layers of **meaning** that emerge from complex signaling patterns.

**4. No Fixed Layers:
- **Non-Prescriptive Structure**: There are no predetermined layers or levels. The network's architecture is **flexible** and can reorganize itself based on the relational dynamics.
- **Adaptability**: This allows the network to **adapt** seamlessly to new information or changes within the system, modifying its hierarchical organization as needed.

**5. Mathematical Framework:
- **Category Theory**: Rogers employs **category theory**, focusing on **morphisms** (relationships) rather than objects. This mathematical approach is adept at modeling complex, relational structures where hierarchies emerge from interaction patterns.

AI Neural Networks
**1. Entity-Centric Nodes:
- **Defined Nodes**: In AI, nodes (neurons) have predefined roles and activation functions. They process inputs and produce outputs based on **weighted connections**.
- **Static Identity**: Each neuron's function and identity are set by its place in the network and do not change dynamically based on interactions.

**2. Predefined Hierarchical Structure:
- **Layered Architecture**: Neural networks are organized into layers—**input**, **hidden**, and **output** layers. The hierarchy is **prescribed** by the network's architecture.
- **Fixed Hierarchies**: The number of layers and the connections between neurons are typically fixed when the network is designed.

**3. Learning Through Weight Adjustment:
- **Backpropagation**: Hierarchical learning occurs through **adjusting weights** during training. While weights change, the overall structure remains static.
- **Function Approximation**: The network learns to approximate functions by mapping inputs to outputs through the hierarchical layers.

**4. Data Flow and Processing:
- **Feedforward and Feedback**: Information flows in a **feedforward** manner, and in some architectures, there is feedback (e.g., recurrent neural networks).
- **Hierarchical Feature Extraction**: Each layer extracts features at different levels of abstraction, building complexity as data moves up the hierarchy.

**5. Mathematical Framework:

- **Linear Algebra and Calculus**: AI networks rely on these mathematical foundations to compute outputs and update weights efficiently.

Comparing Hierarchy Formation

1. Emergent vs. Prescribed Hierarchies:
- **Rogers**: Hierarchies **emerge naturally** from the dynamic interplay of nodes. There are no predetermined levels; the structure is shaped by ongoing interactions and the exchange of meaning.
- **AI**: Hierarchies are **designed** into the network. Layers and connections are set up front, with the hierarchy serving as a scaffold for learning.

2. Dynamic vs. Static Structures:
- **Rogers**: The hierarchical organization is **fluid**. As nodes interact and new signals are exchanged, the hierarchy can **reconfigure itself**, reflecting changes in the network's state.
- **AI**: The structure is **static**. While weights and activations change during training, the hierarchical architecture remains fixed unless manually altered.

3. Role of Relationships:
- **Rogers**: Relationships are **fundamental**. Nodes exist because of their relationships, and these relationships continuously redefine the hierarchy.
- **AI**: Relationships (weights) are important but secondary to the predefined structure. They adjust to improve performance but do not redefine the hierarchy.

4. Incorporation of Meaning and Context:
- **Rogers**: Hierarchies are shaped by **semiotic processes**. The **meaning** generated through node interactions influences the network's organization.
- **AI**: Hierarchical processing is primarily about mathematical transformations of data. **Meaning** is not explicitly considered; it's an emergent property of data representation.

5. Adaptability and Evolution:
- **Rogers**: The network can **adapt** its hierarchical structure in real-time, allowing it to respond to new stimuli or changes in the environment dynamically.
- **AI**: Adaptation occurs through **learning within the existing hierarchy**. Changing the hierarchical structure typically requires re-engineering the network.

Implications in Hierarchical Formation

1. Flexibility and Adaptation:
- **Rogers' Networks** can model complex, adaptive systems more naturally due to their ability to reorganize hierarchies on the fly.
- **AI Networks** are powerful within their designed scope but may struggle with scenarios that require structural adaptation without redesign.

2. Contextual Sensitivity:
- **Rogers' Approach**: Hierarchies are sensitive to context, as meaning influences structure. This allows for more nuanced responses to complex, changing environments.
- **AI Approach**: Context must be encoded into the input data or handled through specific architectural choices but doesn't alter the hierarchy itself.

3. Emergence of Complex Behaviors:

- **Rogers**: Complex behaviors and higher-order structures **emerge** from simple rules of interaction, similar to phenomena in natural systems like ant colonies or neural processes.
- **AI**: Complexity is built through stacking layers and increasing parameters, often requiring substantial computational resources.

4. Mathematical Representation:
- **Category Theory** in Rogers' networks provides tools for modeling transformations and relationships at a high level of abstraction, potentially capturing more nuanced hierarchical dynamics.
- **Linear Algebra** in AI networks is suited for numerical computation but may not capture the richness of relational dynamics without significant complexity.

Illustrative Metaphor

Imagine a **forest ecosystem** versus a **factory assembly line**:
- **Rogers' Nodal Network (Forest)**: The hierarchy of the forest—canopy, understory, shrubs, soil—is not pre-designed but emerges from the interactions of plants, animals, and microorganisms. Changes in one part of the ecosystem can dynamically reshape the entire hierarchy, fostering a resilient and adaptable environment.
- **AI Neural Network (Assembly Line)**: The assembly line has a fixed structure with specific stages—each worker (node) has a predefined role. Efficiency comes from this established hierarchy, but adapting to produce a new product requires retooling the entire system.

Potential Cross-Pollination
- **Adaptive AI Architectures**: Incorporating Rogers' principles could inspire AI networks that can **dynamically adjust** their structures, leading to more robust learning in unpredictable environments.
- **Understanding Biological Systems**: His approach aligns more closely with how **biological neural networks** (brains) might reorganize themselves through neuroplasticity, offering insights into more naturalistic AI.
- **Semantic Understanding**: Emphasizing meaning and semiotics could enhance AI's ability to understand and generate human language and symbols more profoundly.

Final Thoughts

Rogers' nodal networks challenge us to rethink hierarchy not as a rigid scaffold but as a living, breathing structure, constantly evolving through relationships and meanings. In contrast, AI neural networks provide powerful but **structurally static** hierarchies optimized for specific computational tasks.

By examining these differences, we open doors to new paradigms in AI where systems could:
- **Self-Organize**: Adjust their architectures in response to new data or tasks without external intervention.
- **Interpret Context**: Integrate contextual meaning directly into their processing, improving decision-making and interaction.

- **Emulate Natural Systems**: More closely mimic the adaptability and resilience found in natural networks, from neural pathways in the brain to social networks.

Exploring Rogers' approach offers a pathway toward AI that is not just intelligent but also **deeply integrated** with the relational and meaning-filled fabric of the world.

References

[Author unknown]. 1990. *I Ching,* translated by Richard Wilhelm and rendered into English by Cary Baynes. Princeton: Princeton University Press.

Augustine, Saint. 2008. *Confessions*, *Book XI*, translated by Henry Chadwick. Oxford: Oxford University Press.

Augustine, Saint. 1996. *Teaching Christianity* (*De Doctrina Christiana)*, edited by John E. Rotelle, translated by Edmund Hill. Hyde Park: New York City Press.

Barad Karen. 2007. *Meeting the Universe Halfway: Quantum Physics and Entanglement of Matter and Meaning*. Durhan and London: Duke University Press.

Bohm, David. 1980. *Wholeness and the Implicate Order*. London: Routledge.

Deacon, Terrence W. 2011. *Incomplete Nature: How Mind Emerged from Matter*. New York: WW Norton & Company.

Deely, John. 2009. *Purely Objective Reality*. Berlin and New York: Mouton de Gruyter.

Ellerman, David. 2024. *A Fundamental Duality in the Mathematical and Natural Sciences: From Logic to Biology*. DOI: https://doi.org/10.48550/arXiv.2409.18134

Favareau, Donald. 2015. Symbols are grounded not in things, but in scaffold relations and their semiotic constraints (or how the referential generality of semiotic scaffolding grows minds). *Biosemiotics,* 8: 235-55. DOI: https://doi.org/10.1007/s12304-015-9234-3

Feynman, Richard P. 2006. *QED: The Strange Theory of Light and Matter*. Princeton: Princeton University Press.

Hegel G.W.F. 1979. *Phenomenology of Spirit*, translated by A.V. Miller. New York: Oxford University Press.

Howard, Don. 1985. Einstein on locality and separability. *Studies in History and Philosophy of Science*, 16(3):171-201. DOI: https://doi.org/10.1016/0039-3681(85)90001-9

Jaki, Stanley L. 1992. *Genesis 1 Through the Ages*. Chicago: Thomas More Press.

Kastner, Ruth E. 2012. *The Transactional Interpretation of Quantum Mechanics: The Reality of Possibility.* Cambridge: Cambridge University Press.

Kull, Kalevi. 2023. Freedom in living beings: Arbitrariness and the forms of semiotic indeterminacy. In *Open Semiotics, Vol4. Life and its Extensions.* Bilgari, Amir (Ed.), L'Hartmattan, 79-95.

Levinas, Emmanuel. 2002. *Otherwise than Being or Beyond Essence*. Translated by Alphonso Lingus. Pittsburgh: Duquesne University Press.

Makridakis, Ari. 2024. *The Matrix of Possibility: A Systems-based Metaphysics for Evolutionary Cosmology*. PhD dissertation. California Institute of Integral Studies. [https://www.proquest.com/docview/3056672952/1D3C445ECE7B4A36PQ/4, accessed February 19, 2025].

Maudlin, Tim. 2019. *Philosophy of Physics: Quantum Theory.* Princeton: Princeton University Press.

Oldofredi, Andrea. 2023. The Relational Dissolution of the Quantum Measurement Problems. *Foundations of Physics* 53,10. DOI: https://doi.org/10.1007/s10701-022-00652-z

Peirce, Charles Sanders. 1931-1958. *The Collected Papers of Charles Sanders Peirce*, Vol 1-8. Havard University Press. [Cited as *CP*].

Rogers, Timothy. 2022. *Études in Light and Harmony: An Interdisciplinary Workbook for Creative Dialogue and Discovery*. DOI: https://dx.doi.org/10.2139/ssrn.3875673

Rogers, Timothy. 2024. A formal model of primitive aspects of cognition and learning in cell biology as a generalizable case study of the threefold logic of Peircean semiotics in natural systems. *Sign Systems Studies*, 52(1-2): 8-48. DOI: https://doi.org/10.12697/SSS.2024.52.1-2.01

Rosen, Robert. 1991. *Life Itself: A Comprehensive Inquiry into the Nature, Origin, and Fabrication of Life*. New York: Columbia University Press.

Rovelli Carlo. 1996. Relational Quantum Mechanics. *International Journal of Theoretical Physics,* 35:1637-78. https://doi.org/10.1007/BF02302261

Schofield James. 2021. *A Phenomenological Revision of E.E. Harris's Dialectical Holism*. Cham: Springer.

Smolin, Lee. 2006. *The Trouble with Physics: The Rise of String Theory, the Fall of a Science, and What Comes Next*. Boston: Houghton Mifflin Harcourt

Somers-Hall, Henry. 2012. *Hegel, Deleuze, and the Critique of Representation: Dialectics of Negation and Difference*. Albany: State University of New York.

Spencer-Brown, George. 1969. *Laws of Form.* New York: Julian Press.

Unger, Roberto Mangabeira, and Smolin, Lee. 2015. *The Singular Universe and the Reality of Time: A Proposal in Natural Philosophy*. Cambridge: Cambridge University Press.

Vassallo, Antonio, Naranjo, Pedro, and Kolowski, Tim. 2022. "The Physics and Metaphysics of Pure Shape Dynamics." In *The Foundations of Spacetime Physics: Philosophical Perspectives*,

edited by Antonio Vassallo. New York: Routledge. DOI:
https://doi.org/10.48550/arXiv.2203.02773

White, Thomas Joseph. 2022. *The Trinity: On the Nature and Mystery of the One God*.
Washington DC: Catholic University Press.

Whitehead, Alfred North and Russell, Bertrand. 1910-1913. *Principia Mathematica.* Cambridge:
Cambridge University Press.

Zalamea, Fernando. (N.d.). *Peirce's Logic of Continuity: A Conceptual and Mathematical
Approach*. [https://www.academia.edu/31948393/ZalameaPeirceCont_pdf, accessed February 2,
2025].

Zwick, Martin. 2023. *Elements and Relations: Aspects of a Scientific Metaphysics*. IFSR
International Series in Systems Science and Systems Engineering. Cham: Springer.

Zwicky, Jan. 2003. *Wisdom & Metaphor*. Kentville NS, Canada: Gaspereau Press.