The Relationship Between Systems Theory, Causality and Symbolic Reasoning

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Abstract

This article develops a unified formal framework linking systems theory, causality, and symbolic reasoning, showing that these domains are not distinct explanatory layers but different perspectives on the same underlying physical structure. Symbolic reasoning is an enhanced form of set theory grounded in physical entities, relationships, and transfers, rather than as an abstract or disembodied formalism.

Within this framework, causal relationships are understood as structured transfers of matter, energy, or information, while systems are understood as organised configurations of such relationships that transform inputs into outputs. Two complementary modes of causality are distinguished: event-centred (PTP) causality, which focuses on transfers between entities, and system-centred (TPT) causality, which focuses on transformational processes within systems. Necessary and sufficient causes, alternative causal pathways, and multiple outputs are represented explicitly using a small, consistent symbolic vocabulary.

The framework further formalises capability or potential as a property of systems independent of their current functioning, thereby grounding dispositional causality without invoking non-physical entities. Information is treated as physical structure, leading naturally to formal accounts of information at source (negentropy), observation, communication, and misinformation as causal processes involving information transfer. Epistemic states such as knowing, learning, and testimony are shown to arise from physical configurations of information held by agents or media.

Finally, a distinction is drawn between giving, receiving, and taking, allowing agency and control to be represented without departing from the causal ontology. The result is a single coherent symbolic language capable of representing systems, events, causality, information, and agency within the constraints of formal logic, providing a foundational unification of natural language, systems theory, causal analysis, logic, and mathematics.

1. Introduction

This article sets out the relationship between Systems Theory, Causality, and Symbolic Reasoning, and shows that these are not separate domains but different perspectives on the same underlying physical structure.

Symbolic Reasoning, as used here, is an enhanced form of set theory that allows natural language statements, logical relations, and mathematical expressions to be represented within a single formal system. Unlike conventional formal logic, it is explicitly grounded in physical entities, processes, and transfers, rather than treating symbols as abstract or disembodied.

The central claim of this article is that systems, causal events, and acts of reasoning all share the same underlying structure. Systems can be understood as organised patterns of causal relationships; causal relationships can be understood as structured transfers between physical entities; and symbolic reasoning can be understood as the formal manipulation of representations of those same structures.

By expressing systems theory and causality in symbolic form, this framework makes it possible to reason within and across disciplines, including natural language, logic, mathematics, systems theory, and causal analysis, using a single, coherent formal language. As a result, reasoning about physical, biological, social, and cognitive phenomena can be carried out within the constraints of logic, allowing claims to be formally tested, compared, and, where appropriate, proven or disproven.

This article is foundational in intent and does not attempt empirical application; that is addressed elsewhere.

2. Symbolism

This section introduces the symbolic conventions used throughout the paper. These symbols are not arbitrary: each corresponds to a physical entity, a relationship, or a logical operation. Once introduced here, they are used consistently in all later sections.

We begin by distinguishing between collections and singular entities.

Let **a** represent a plural collection of physical entities or relationships. Let $\mathbf{a}^1$ represent either a single physical entity or the same collection **a** treated as a single entity. This distinction allows us to refer both to components and to the aggregate system they form.

Relationships are represented using the symbols **S** (subject) and **Q** (object). If $\mathbf{x}^1$ is a relationship, then:

$\mathbf{Sx}^1$ denotes the *subject* of the relationship: the physical entity from which the relationship originates.

$\mathbf{Qx}^1$ denotes the *object* of the relationship: the physical entity toward which the relationship is directed.

Because physical entities typically participate in many relationships, we also define:

${}^{V}\mathbf{Sa}^1$ as the collection of relationships for which $\mathbf{a}^1$ is the subject.

${}^{V}\mathbf{Qb}^1$ as the collection of relationships for which $\mathbf{b}^1$ is the object.

The direction of any relationship $\mathbf{x}^1$ is from subject to object. Its reverse, ${}^{V}\mathbf{x}^1$, represents the same relationship viewed in the opposite direction. In this sense, **S** and **Q** define directional roles within relationships rather than distinct kinds of entities.

Set-theoretic and logical symbols are used as follows:

$\subseteq$ means “is a subset of or equal to”.

E denotes the universal set.

$\emptyset$ denotes the null set.

The dot operator **(.)** denotes logical *and*, or a conjunction of collections.

The plus operator **(+)** denotes logical *or*, or a disjunction of collections.

Example

If $\mathbf{a}^1$ is a pump and $\mathbf{b}^1$ is a tank, then:

${}^{V}\mathbf{Sa}^1$ represents all outputs from the pump,

${}^{V}\mathbf{Qb}^1$ represents all inputs to the tank,

and a specific relationship $\mathbf{x}^1$ might represent the flow of fluid from pump to tank.

3. Relationships

This section distinguishes between the two fundamental kinds of relationships that occur between physical entities. This distinction underpins everything that follows, including causality, systems, information, and agency.

Relationships are of two types: causal and configurational.

- **Causal relationships** involve the transfer of something physical, i.e., matter, energy, or information, from one entity to another.
- **Configurational relationships** involve no such transfer. Instead, they describe how entities are arranged relative to one another in space-time, structure, or organisation.

In other words, causal relationships describe doing, while configurational relationships describe arrangements.

Configurational relationships capture facts such as proximity, containment, ordering, or orientation. Although nothing is transferred, these relationships are not incidental: they often constrain or enable causal relationships.

Example

A wire connected to a battery is a *configurational* relationship. Electric current flowing through that wire is a *causal* relationship. Both are necessary to understand how the system functions, but only one involves transfer.

4. Causal Relationships

Causal relationships can be understood in two complementary ways:

- As relationships between entities, and
- As physical entities in their own right, namely the matter, energy, or information that is transferred.

These two perspectives are paired.

If $\mathbf{r^1}$ is a causal relationship, then $\mathbf{Tr^1}$ denotes the physical entity transferred by that relationship. Conversely, if $\mathbf{c^1}$ is a transferred physical entity, then $\mathbf{{}^{V}Tc^1}$ denotes the causal relationship through which it is transferred.

Here, **T** is a pairing relationship that links a causal relationship with the physical entity it transfers, and $\mathbf{{}^{V}T}$ is its reverse.

This pairing allows causal structure to be represented without changing the underlying ontology either:

- in terms of events and relationships, or
- in terms of flows and transfers.

Configurational relationships are formally distinguished by the fact that they involve no transfer. If $\mathbf{s^1}$ is a configurational relationship, then:

$\mathbf{Ts^1} = \emptyset$

This expression serves as a defining property of configurational relationships.

Examples

Heat flowing from a hot object to a cold one is a causal relationship $\mathbf{r^1}$; the heat energy is $\mathbf{Tr^1}$.

Two gears being meshed but stationary form a configurational relationship $\mathbf{s^1}$; but $\mathbf{Ts^1} = \emptyset$.

5. Enabling and Inhibiting Causes

Not all causes directly produce effects. Some causes enable processes to occur, while others inhibit them. An enabling cause allows a process within a system to function and deliver its outputs. An inhibiting cause interferes with or prevents that functioning.

In social systems, a different terminology is used:

- Processes are often described as *needs*.
- Enabling causes are referred to as *satisfiers*.
- Inhibiting causes are referred to as *contra-satisfiers*.

This terminology reflects the fact that many causal relationships do not create outcomes directly, but instead modulate whether internal processes are able to operate.

Examples

Fuel enables an engine to run but does not determine where the vehicle goes.

A blocked airway inhibits breathing thereby preventing a cause, oxygen, from enabling life.

6. Events

We now introduce the symbolic representation of events.

The expression $\mathbf{{}^{V}Sa^1.x.{}^{V}Qb^1}$ describes a relationship of type $\mathbf{x}$ between the physical entities $\mathbf{a^1}$ and $\mathbf{b^1}$.

If $\mathbf{x}$ is a causal relationship, then this expression represents an event. That is, something doing something to something else. In physical terms, it describes the transfer of matter, energy, or information from $\mathbf{a^1}$ to $\mathbf{b^1}$.

This expression also represents a component in PTP causality, where events function as causes or effects.

The temporal ordering implicit in the expression is left-to-right:

- Output from $\mathbf{a^1}$
- Transfer via relationship $\mathbf{x}$
- Input to $\mathbf{b^1}$

Because $\mathbf{{}^{V}Sa^1.x.{}^{V}Qb^1}$ is a statement, it has a truth value. Its truth or falsity can be expressed by equating it to the null set:

- $\mathbf{{}^{V}Sa^1.x.{}^{V}Qb^1} \neq \emptyset$ means the event occurs.
- $\mathbf{{}^{V}Sa^1.x.{}^{V}Qb^1} = \emptyset$ means the event does not occur.

Formally, this can be generalised as:

$$\mathbf{((a^1 \neq \emptyset) = E) \subseteq ((a^1 \subseteq x{*}b^1) = ({}^{V}Sa^1.x.{}^{V}Qb^1 \neq \emptyset))}$$

(See references for the full interpretation of this expression.)

Every event also has a reverse. For example, the collection of events $\mathbf{{}^{V}Sa^1.c.{}^{V}Qb^1}$ has the collection of reverses $\mathbf{{}^{V}Qa^1.{}^{V}c.{}^{V}Sb^1}$. This mirrors the distinction between active and passive constructions in natural language.

The functions $^{V}\mathbf{S}$ and $^{V}\mathbf{Q}$ define relationships from physical entities, and **x** is itself a collection of relationships. Their conjunction is therefore a relationship. To recover the transferred physical entities, an operation is required:

$\mathbf{T(^{V}Sa^{1}.x.^{V}Qb^{1})}$

This denotes all matter, energy, or information transferred from $\mathbf{a^1}$ to $\mathbf{b^1}$ by a relationship of type **x**, and can be decomposed as:

$\mathbf{T(^{V}Sa^{1}.x.^{V}Qb^{1}) = T^{V}Sa^{1}.Tx.T^{V}Qb^{1}}$

If **c** is the collection of physical entities transferred by the causal relationships **x**, then $\mathbf{x = {}^{V}Tc}$, and the expression becomes:

$\mathbf{T(^{V}Sa^{1}.^{V}Tc.^{V}Qb^{1}) = T^{V}Sa^{1}.c.T^{V}Qb^{1}}$

Example

A hammer ($\mathbf{a^1}$) striking a nail ($\mathbf{b^1}$) transfers momentum (**x**). The event exists if and only if that transfer occurs.

7. Systems

Having defined events as causal relationships between entities, we now turn to systems.

Where events describe *something happening*, systems describe *something functioning*.

The expression $\mathbf{Qx.b^{1}.Sy}$ describes a physical entity $\mathbf{b^1}$ that is:

- the object of relationships of type **x**, and
- the subject of relationships of type **y**.

If **x** and **y** are collections of causal relationships, then **x** includes inputs to $\mathbf{b^1}$, and **y** includes outputs from $\mathbf{b^1}$. In this case, the expression represents a process or system. That is, a physical entity that transforms inputs into outputs.This symbolism therefore represents *something converting some things into other things*.

It also represents a causal component in TPT causality, where systems act as causes and effects by virtue of the transformations they perform.

The temporal ordering is again left-to-right:

- Inputs conveyed by an **x**
- Processing by $\mathbf{b^1}$
- Outputs conveyed by a **y**

Because $\mathbf{Qx.b^{1}.Sy}$ refers to a physical entity, its existence can be expressed using the null set:

- $\mathbf{Qx.b^{1}.Sy \neq \emptyset}$ means the system exists and is functioning.
- $\mathbf{Qx.b^{1}.Sy = \emptyset}$ means the system does not exist or is not functioning.

Because $^{V}\mathbf{S}$ and $^{V}\mathbf{Q}$ are one-to-many relationships, there is no direct analogue here to the formal equivalence $\mathbf{((a^{1} \neq \emptyset) = E) \subseteq ((a^{1} \subseteq x{*}b^{1}) = (^{V}Sa^{1}.x.^{V}Qb^{1} \neq \emptyset))}$ used earlier for events.

The functions **Q** and **S** define physical entities from relationships, and $\mathbf{b^1}$ is itself a physical entity. Their conjunction is therefore a physical entity. If we wish to convert it into a relationship, an operation would be required:

$\mathbf{^{V}T(Qx.b^{1}.Sy)}$

Since **T** is a pairing relationship, this implies that every system can, in principle, be transferred between larger systems, for example, as a component, module, or subsystem.

Example

A lung (**b**^{1}) receives unoxygenated blood (**x**) and outputs oxygenated blood (**y**). The lung is a system because it transforms what it receives into what it delivers.

8. Causality

Causality can be analysed in two complementary but distinct ways: PTP causality and TPT causality. Both are valid, but they focus attention on different causal elements.

TPT Causality (system-centred)

In TPT causality, the causal components are physical systems with inputs and outputs. These systems are linked by common transfers (T), but the focus is on the P element: the internal processes that transform inputs into outputs.

In many real-world cases, the actual transfers are unknown or unobservable. Instead, we recognise patterns of relationships between systems. This form of reasoning relies heavily on pattern recognition therefore and is often carried out unconsciously.

TPT causality forms the foundation of many statistical and epidemiological approaches, including Ken Rothman's sufficient component cause model, where mechanisms are inferred without explicitly identifying transfers.

The limitation of this approach is that it does not, by itself, confirm true causality. Two systems may appear causally linked while in fact sharing a common cause. TPT causality is, however, indispensable for discovery, even where it is insufficient for confirmation.

PTP Causality (event-centred)

In PTP causality, the causal components are events. That is, something doing something to something else. These events are linked by a common P, understood here as a physical entity participating in multiple events.

In this case, the focus is on T, the transferred matter, energy, or information. Because both transfers and participating entities are known, this form of reasoning allows true causality to be confirmed.

PTP causality is therefore more explicit, more conscious, and more mechanistic.

Relationship between the two

TPT causality excels at recognising *that* something is happening. PTP causality excels at explaining *how* it is happening. A complete causal account requires both.

9. Necessary and Sufficient Causes

A system may require **multiple inputs** in order to function. Individually, these inputs may be necessary but not sufficient. Only together do they enable the system to operate or produce an effect.

Such jointly sufficient causes can be expressed as:

Qx^1.Qy^1.Qz^1

This expression denotes that inputs $\mathbf{x^1}$, $\mathbf{y^1}$, and $\mathbf{z^1}$ must all be present for the system to function.

However, a system may also have alternative sufficient causes: different combinations of inputs that can independently enable the same process. These can be expressed as:

$\mathbf{Q(u^1 + v^1 + w^1)}$

This symbolism allows necessary, sufficient, and alternative causal pathways to be represented explicitly and without ambiguity.

Example

A fire may require fuel *and* oxygen *and* ignition. But ignition could be supplied by a match *or* a spark *or* friction.

10. Multiple Outputs

A functioning system may produce multiple outputs. These outputs may occur together or independently.

Multiple simultaneous outputs can be expressed as:

$\mathbf{Sx^1.Sy^1.Sz^1}$

Alternative outputs can be expressed as:

$\mathbf{S(u^1 + v^1 + w^1)}$

Using the logical operators **(.)** and **(+)**, this formalism allows causal chains, convergences, and divergences to be represented clearly.

In this way, complex causal structures, including branching processes and feedback loops, can be described using a small number of consistent symbolic rules.

Example

A factory may produce heat, noise, and products simultaneously. Under different conditions, it may produce one product *or* another.

11. Necessity and Sufficiency of Inputs to Systems

Necessity and sufficiency are not intrinsic properties of events or entities in isolation, but relational properties of inputs relative to system behaviour**.** Within a systems framework, they are therefore most naturally expressed in terms of the conditions under which a system produces, or fails to produce, particular outputs.

Let $\mathbf{b^1}$ denote a system operating within a specified systems context and level of granularity, and let **y** denote a particular type of output of that system. Inputs to the system may act as enablers, which permit or promote the production of outputs, or as inhibitors, which prevent or suppress them.

Necessary Enablers

An input of type **x** is *necessary* for system $\mathbf{b_1}$ to produce output of type **y** if **y** does not occur in the absence of **x**. This can be expressed symbolically as:

$\mathbf{b^1.Sy \subseteq Qx}$

This expression states that whenever **b^1** outputs a **y**, an input **x** must have been received. Necessity, in this sense, constrains the conditions under which an output may occur, but does not imply that the input alone is sufficient to produce that output.

Sufficient Enablers

An input of type **x** is *sufficient* for system **b^1** to produce an output of type **y** if the presence of an **x**, under the specified system context, guarantees that **y** occurs. This is expressed as:

$Qx.b^1 \subseteq Sy$

Sufficiency is therefore a stronger condition than necessity and is always context-dependent. It presupposes that no effective inhibitors are present and that the system is in a state capable of realising the relevant input–output transformation.

Necessary Inhibitors

An inputof type **i** is *necessary* to inhibit system **b^1** from producing an output of type **y** if **y** does not fail to occur in the absence of **i**. Equivalently, if a **y** occurs, then an **i** must not have been applied. This can be expressed as:

$b^1.Sy \subseteq {\sim}(Qi)$

Here, the negation operator applies to the entire input relationship, so **~(Qi)** denotes the absence of an inhibitory input **i**. This formulation captures the idea that an **i** is required to prevent the output, rather than to produce it.

Sufficient Inhibitors

An inputof type **i** is *sufficient* to inhibit system **b^1** from producing an output of type **y** if its presence guarantees that a **y** does not occur. This is expressed as:

$Qi.b^1 \subseteq {\sim}(Sy)$

This statement asserts that whenever the inhibitor **i** is applied to **b_1**, the output **y** is absent.

Mutual Exclusivity and Null Results

Because sufficient enablers and sufficient inhibitors impose mutually exclusive constraints on system behaviour, their conjunction yields no admissible system output. For example, conjoining a sufficient enabler for an output of type **y** with a sufficient inhibitor for an output of type **y** results in the null set within the systems context. This does not indicate a logical inconsistency, but rather that no valid system behaviour exists under those combined conditions.

Accordingly, null results in this framework represent the exclusion of inadmissible causal configurations rather than the non-existence of physical entities.

12. Capability or Potential

A crucial distinction in causal reasoning is the difference between what a system is and what a system can do.

Let **b^1** represent a system that is capable of functioning irrespective of whether or not it is actually functioning.

Let **$Qx.b^1.Sy$** represent the same system when it is fully functioning, that is, when it is receiving appropriate inputs and delivering all of its possible outputs.

The system's full capability can then be expressed as:

$$\mathbf{Qx.b^1.Sy} \neq \emptyset$$

This expression states that the system is actually functioning in that way.

The logically valid inclusion relation:

$$\mathbf{Qx.b^1.Sy} \subseteq \mathbf{b^1}$$

expresses the fact that if $\mathbf{b^1}$ actually does perform these functions, then it must capable of doing so. This relation therefore defines the capabilities or potential of $\mathbf{b^1}$.

Capabilities can also be expressed at a finer level of detail. For example:

$$\mathbf{Qx.b^1.Sy.Sz} \subseteq \mathbf{b_1}$$

means that $\mathbf{b^1}$ is capable of producing outputs of type **y** and **z**, given appropriate inputs.

If the system actually produces a specific output, this is expressed as:

$$\mathbf{b^1.Sy} \neq \emptyset$$

This distinguishes clearly between:

- capability (what the system could do), and
- functioning (what the system is doing).

Example

A muscle can contract even when it is at rest. The ability to contract is a capability; contraction itself is a functioning.

13. Systems, Systemness, and Levels of Emergence

Having defined what systems are capable of doing, we now specify which entities qualify as systems at all.

Not all physical entities, nor all assemblies of entities, constitute systems. Let **s** denote the collection of systems, defined by the characteristic *systemness*, a characteristic that applies only to a subset of entities. An entity is a system if and only if it is capable of accepting inputs, processing them, and delivering outputs, where these capabilities constitute emergent causal properties not possessed by its component systems. Systemness is therefore not merely a property of composition.

An entity may be composed of systems without itself being a system; an assembly of systems forms a supra-system only if emergent causal capability arises at that level. Where such emergence does not occur, the assembly does not qualify as a system.

Systemness is also level-dependent. A system at one level of granularity may be composed of component systems at a finer level and may participate as a component within assemblies at coarser levels. Emergent properties, however, arise at specific levels of organisation. An entity may therefore qualify as a system at one level, function as a component at another, or fail to qualify as a system at a given level altogether.

Within a systems context, which can be denoted by a contextual declaration such as:

s:

the domain of discourse is restricted to members of **s**. Any entity that does not satisfy the criterion of systemness is null within this context, even though it may exist as a physical entity outside the systems domain.

Accordingly, the formal expressions introduced earlier, such as **Qx.b^1.Sy**, apply only to entities that qualify as systems at the level of analysis under consideration. Where systemness is absent, such expressions are null and excluded from system-level analysis.

Thus, within the context declaration **s:**

- if **a^1** is a system then **a^1**$\neq \emptyset$ within the systems context.
- if **a^1** is not a system then **a^1**$= \emptyset$ within the systems context.

Sub-systems of **a^1** at the first level of granularity are those component subsystems of **a^1** that are not themselves composed of sub-systems, i.e. **({⊂}a^1).({⊂}<u>∗</u>{⊂}a^1).**

Supra-systems of a collection **a** at the first level of assembly are those admissible entities that incorporate all members of **a**, but are not themselves supra-systems of lower-level supra-systems, i.e., **({⊃}◇a).({⊃}<u>∗</u>{⊃}◇a)**. If **a** are insufficient to form a system then this expression is null.

(See references for the full interpretation of these expressions.)

14. Information

Having defined systems, capability, and functioning, we now turn to information.

Suppose that a system is fully functioning and is represented by: **Qx.b^1.Sy**

The information content of this functioning system is symbolised as: **"Qx.b^1.Sy"**

That is, the information corresponds to the fact *that this system functions in this way*. Information is therefore static or dynamic structure carried on a physical substate of matter or energy. Information is not a relationship. Rather it is a physical entity, but it *represents* relationships.

All items of information are treated as singular entities, regardless of their apparent complexity. Formally:

"Qx.b^1.Sy" = ("Qx.b^1.Sy")^1

This reflects the fact that any specific item of information is a single physical object, for example, a pattern of neural activity, a written statement, or a stored digital record.

Crucially, information is physical. It consists of structured matter or energy and therefore:

- can participate in causal relationships,
- can be transferred,
- can be transformed,
- and can itself act as a cause or be an effect.

Example

A diagram of an engine is not the engine, nor a relationship between parts; it is a physical object that represents how the engine functions.

15. Information at Source (Negentropy)

A functioning system not only produces outputs; it also embodies information about its own structure and operation. If:

Qx.b^1.Sy

is a functioning system, then it holds the information:

"$Qx.b^1.Sy$"

This relationship can be expressed formally as:

$$Qx.b^1.Sy \subseteq H(\text{"}Qx.b^1.Sy\text{"})^1$$

This expression describes information at source: the information inherent in a system by virtue of its organised structure and functioning.

This conception of information aligns with the idea of negentropy: organised structure that constrains degrees of freedom and makes specific states distinguishable.

Example

A working clock contains information about timekeeping simply by being organised to tick regularly. That information exists even if no one observes the clock.

16. Agents and Media

Information need not be constrained at its source. It can be held, stored, and carried by other physical entities. Agents and media are physical entities capable of holding information. If $\mathbf{a^1}$ is an agent or medium, then:

$$a^1 \subseteq H(\text{"}Qx.b^1.Sy\text{"})^1$$

means that $\mathbf{a^1}$ holds the information **"$Qx.b^1.Sy$"**.

Conversely:

$$\text{"}Qx.b^1.Sy\text{"}^1 \subseteq {}^{V}Ha^1$$

means that the information **"$Qx.b^1.Sy$"** is held by $\mathbf{a^1}$.

Holding information in this way corresponds to familiar epistemic states:

- *knowing*,
- *knowing of* (if acquired indirectly),
- *knowing that* (if propositional).

If **"$Qx.b^1.Sy$"** is replaced by a physical entity $\mathbf{c^1}$, this represents *knowing that thing*, rather than *knowing that a statement is true*.

Thus, epistemic states are not primitives. They are physical configurations of information held by agents or media.

Example

A book holds information about a historical event. A person who reads the book comes to hold that information in a different medium.

17. Observation

Observation is the process by which information is transferred from its source to an agent.

Let a functioning system be represented by:

$$Qx.b^1.Sy$$

and let $\mathbf{a^1}$ be an agent capable of holding information.

Observation can then be expressed as:

$\mathbf{^{V}S(Qx.b^{1}.Sy).^{V}T(\text{“}Qx.b^{1}.Sy\text{”}).^{V}Qa^{1}}$

This expression states that the functioning system $\mathbf{Qx.b^{1}.Sy}$ transfers its information, that is, the physical entity **“**$\mathbf{Qx.b^{1}.Sy}$**”**, to the agent $\mathbf{a^{1}}$.

Observation is therefore a causal process, not a passive relation. It involves:

- A source that embodies information,
- A transfer of that information,
- An agent that receives and holds it.

At classical and higher levels of organisation, information is embodied in stable physical structures and may be replicated without consuming or altering the original at its source. This need not hold at sub-atomic scales, where observation may alter the state of the system.

Acquiring information in this way corresponds to familiar experiential states such as:

- experiencing,
- perceiving,
- learning from direct experience,
- learning that something is the case.

Example

A thermometer displays a temperature. A person reads the display and acquires the information without altering the temperature itself.

18. Communication

Communication is the process by which information is transferred between agents or media, rather than directly from its original source.

Let $\mathbf{c^{1}}$ be an agent or medium that already holds the information **“**$\mathbf{Qx.b^{1}.Sy}$**”**, and let $\mathbf{a^{1}}$ be another agent.

Communication can be expressed as:

$\mathbf{^{V}Sc^{1}.^{V}T(\text{“}Qx.b^{1}.Sy\text{”}).^{V}Qa^{1}}$

This expression states that $\mathbf{c^{1}}$ transfers the information **“**$\mathbf{Qx.b^{1}.Sy}$**”** to $\mathbf{a^{1}}$.

Communication is therefore structurally identical to observation, except that the source of the information is an intermediate agent or medium, rather than the original system that generated it.

This formalism captures a wide range of communicative acts, including:

- telling,
- informing,
- teaching,
- hearing,
- learning from testimony,
- reading,
- recording and playback.

As with observation, information can be replicated and transferred without loss of the original.

Example

A scientist observes an experiment and writes a paper. Another scientist reads the paper and acquires the information without observing the experiment directly.

19. Misinformation

Information can be true or false. Misinformation arises when false information is transferred as if it were true.

Because information is physical, its *truth* is constrained by reality. In particular, true information cannot refer to a non-existent entity. Accordingly:

- If **“b_1”.$^{V}Hb_1 \neq \emptyset$**, then **$b_1 \neq \emptyset$**.
- If **$b_1 = \emptyset$**, then **“b_1”.$^{V}Hb_1 = \emptyset$**.

However, the *existence* of information is independent of its truth. Information may exist whether or not it corresponds to reality. Thus:

“b_1” $\neq \emptyset$ means that the information “b_1” exists, irrespective of whether it is true. **“b_1” $= \emptyset$** means that the information “b_1” does not exist.

Truth and falsity are therefore properties of information relative to reality, not conditions of its existence.

If a physical entity **a^1** exists, this is expressed as:

$a^1 \neq \emptyset$

If **a^1** does not exist, this is expressed as:

$a^1 = \emptyset$

Any statement that contradicts the actual state of affairs is false information.

For example, if **$a^1 = \emptyset$**, then the information **“$a^1 \neq \emptyset$”** is false. If such false information is transferred from **b^1** to **c^1**, this can be expressed as:

$(a^1 = \emptyset).(^{V}Sb^1.^{V}T(\text{“}a^1 \neq \emptyset\text{”}).^{V}Qc^1)$

This expression states that **b^1** transfers misinformation to **c^1**.

Importantly, the framework does not require any additional concepts, such as deception, error, or intention, to define misinformation. Misinformation is simply information whose content does not correspond to reality.

Questions of *why* misinformation arises (error, bias, manipulation) can be analysed later in terms of agentic capability, incentives, and constraints.

Example

A faulty sensor reports that a machine is operating when it is not. The report is information, but it is false.

20. Giving, Receiving and Taking

The concepts of giving, receiving, and taking describe different roles that entities may play in causal transfers.

Giving and receiving apply to *all systems*, whether living or non-living.

- When a system produces an output, it gives that output.
- When a system accepts an input, it receives that input.

In both cases, the transfer is defined by the causal relationship itself.

Taking, however, is distinct. Taking is a property only of agents, that is, living systems and some of their artefacts, because it involves selective control over inputs.

- When an agent gives, it is active in deciding that an output will occur.
- When an agent takes, it is also active, but in deciding that an input will occur.

Taking is therefore not the complement of giving. It is an agent-level intervention in the causal process, rather than a property of the transfer itself.

Formally, this distinction can be expressed as:

$\mathbf{b^1 \subseteq \{active\}(^VSa^1.x.^VQb^1)}$

This expression indicates that $\mathbf{b^1}$ is the active agent with respect to the causal relationship, even though it appears as the object of that relationship.

This distinction is crucial for analysing agency, power, responsibility, and control within systems, especially in social and economic contexts.

Example

A tree gives oxygen; it does not choose to do so. A person takes food; they choose when and whether the intake occurs.

21. Conclusion

This article has shown that systems theory, causality, and symbolic reasoning are not separate explanatory frameworks, but different perspectives on the same underlying physical structure.

By treating systems as organised patterns of causal relationships, causal relationships as structured transfers of matter, energy, or information, and symbolic reasoning as the formal manipulation of representations of those same structures, the framework unifies within a single formal language the universal disciplines of:

- natural language,
- causal analysis,
- systems theory,
- logic,
- and mathematics.

This unification allows systems, events, capabilities, information, observation, communication, and agency to be represented, combined, and analysed without introducing new ontological primitives at each level. As a result, reasoning across physical, biological, social, and cognitive domains can be carried out within the constraints of formal logic, allowing claims to be compared, tested, and, where appropriate, proven or disproven.

Symbolising causality and capability in this way significantly simplifies existing analytical methods while revealing their shared structure. It also provides a foundation for extending formal reasoning into domains that are often treated informally or metaphorically, including knowledge, communication, and agency.

In doing so, the framework achieves its central aim: the unification of the universal disciplines into a single, coherent system of symbolic reasoning grounded in physical reality.

22. References

Challoner, J.A. 2022, “The Mathematics of Language and Thought, Vols 1 and 2”, https://rational-understanding.com

Rothman, K. J. (1976). *Causes*. *American Journal of Epidemiology*, 104(6), 587–592.

