The Ontology of Randomness, Structure and Information

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Abstract

This paper develops an ontological account of pattern, structure, and information within a physicalist framework. Building on earlier work establishing entities, space-time, and causality, it addresses a fundamental question: *how is physical reality organised into recurring forms rather than remaining a field of transient and irregular configurations?*

To answer this, the paper introduces and systematically distinguishes the key concepts of randomness, configuration, structure, pattern and information. Randomness is understood as variation without recurring organisation. Configuration is the spatio-temporal arrangement of entities. Structure arises when entities are connected through causal relationships, enabling interaction through transfers of matter, energy, or information. Pattern is the observable manifestation of recurring structure or configuration. Information is then defined as recurring causally organised structure or configuration.

A central claim of the paper is that recurrence requires causality. This establishes causality as a necessary condition for information and grounds recurring pattern in causal organisation rather than in arrangement alone.

The paper further distinguishes between information as an ontological feature of physical reality and information as epistemic content, which arises through interpretation by specific systems. In doing so, it separates physical structure from meaning and avoids conflating objective organisation with observer-dependent interpretation.

The result is a coherent conceptual progression from configuration to information that clarifies what pattern is and establishes the causal conditions under which structures or arrangements recur. The mechanisms underlying recurrence are not developed here but are prepared for in appendices outlining configurational and causal constraints, to be elaborated in subsequent work.

This framework provides a clear ontological foundation for later analysis of systems, environments, constraints, and social organisation, and contributes to a unified understanding of information as an objective feature of causally structured physical reality.

1. Introduction

1.1 Purpose of the Paper

This paper is the third in a series exploring general systems theory. Previous papers were "The Philosophical Foundations of General Systems Theory" and "The Ontological Foundations of General Systems Theory". This third paper examines how physical reality is organised into patterns.

In the earlier papers, we established what exists: entities in space-time, their relationships, and the basic nature of causality. However, this leaves an important question unanswered. Even given entities and relationships, reality does not present itself as a uniform or undifferentiated field. Instead, it exhibits a mixture of irregular, non-recurring arrangements and recurring organisation (Prigogine & Stengers, 1984; Mitchell, 2009).

To account for this, we require a set of concepts that describe not just what exists, but how it is organised. This paper therefore introduces and defines the following concepts: randomness, configuration, structure, pattern, and information. Together, they provide a foundation for understanding pattern and information as objective features of physical reality.

1.2 Position in the Overall Framework

This paper forms a bridge between ontology and systems theory.

- In the first two papers in this series, we established a physicalist ontology (Ladyman et al., 2007): everything that exists is situated in space-time and comprises entities, relationships, and processes.
- In subsequent papers, we will examine systems, environments, constraints, and dynamic interactions.

Between these two stages lies an intermediate question: *How is reality organised into patterns prior to the emergence of systems as identifiable units?*

This paper addresses that question. It focuses on the organisation of entities and the causal relationships between them to explain the concepts of pattern and information. In this sense, the paper provides a pre-system account of pattern and information, establishing the conceptual basis on which later discussions of systems and dynamics depend.

1.3 The Central Problem

The physical world presents a fundamental contrast. Some arrangements are fleeting and irregular. They change without recurrence, and no organisation can be identified.

Other arrangements exhibit recurrence and regularity. They endure, recur, and give rise to identifiable patterns over time.

This contrast is not limited to any one domain. It is evident:

- in physical systems (e.g. dispersed particles versus crystalline solids),
- in biological systems (e.g. random molecular motion versus organised cellular structures), and
- in social systems (e.g. uncoordinated activity versus institutions).

The challenge is to account for this difference in a way that is consistent with a physicalist ontology and does not depend on observation or interpretation.

The question can therefore be stated as: *What distinguishes non-recurring from recurring arrangements, and how does this give rise to pattern and information?*

1.4 Conceptual Progression

To address this question, we introduce a sequence of concepts that build progressively on one another:

Randomness → Configuration → Structure → Pattern → Information

- **Randomness** describes variation without recurring organisation. Randomness may occur in the spatio-temporal arrangement of entities or in the causal networks connecting them.
- **Configuration** describes the disposition of entities in space-time
- **Structure** describes the disposition of entities in space-time together with the network of causal relationships connecting them.
- **Pattern** is the observable manifestation of recurring structure or configuration.
- **Information** describes recurring causally organised structure or configuration.

This conceptual progression is summarised in Figure 1.

Figure 1. *The Core Progression*

This progression does not yet explain why some structures recur while others do not. Rather, it establishes the distinctions necessary to describe pattern as it appears in physical reality.

The mechanisms by which some structures recur will be examined in later papers through the concepts of systems, environments, and constraints.

For now, the task is more fundamental: *to clarify what is meant by arrangement, variation, organisation, and recurring structure.*

2. The Ontology of the Conceptual Progression

2.1 Randomness

Configurations of entities do not in general exhibit regularity. Instead, they may change freely, producing a wide range of transient and non-repeating arrangements. This condition may be described as randomness. Randomness is not the absence of arrangement (Boltzmann, 1974). Rather, it is the presence of variation across arrangements (Mitchell, 2009) that does not lead to recurring forms. Arrangements arise and dissolve without forming patterns over time.

Even in conditions of randomness, arrangements remain subject to the basic limitations of space-time and the properties of entities. Randomness therefore does not imply the absence of constraint, but rather the absence of recurring organisation within those constraints. In this sense, randomness may be understood as the absence of recurring organisation, rather than the absence of constraints altogether. Even in highly variable conditions, entities remain arranged in particular ways at any given moment. What is lacking is not arrangement, but recurrence.

It is therefore important to avoid interpreting randomness as “nothing” or as a lack of order in an absolute sense. Randomness represents non-repeating arrangement, in which no enduring pattern can be identified across time.

Causal networks may also display randomness. That is, the relatative arrangement of two or more causal interactions may also change freely, producing a wide range of transient and non-repeating arrangements.

This concept plays a crucial role in the development of the theory. It establishes the baseline condition against which organised and recurring forms must be understood. If arrangements are free to vary, then the emergence of regularity, and recurrence requires explanation.

The key question that follows is therefore: *Why do some configurations or causal networks give rise to recurring organisation, while others remain non-recurring?*

This question is addressed in a subsequent section, in which the role of causal interaction and the emergence of structure are examined.

2.2 Configuration

At the most basic level, physical reality consists of entities arranged in space-time (Ladyman et al., 2007), i.e., configurations. A configuration specifies: the spatial positions of entities; their relative orientations and distances; and their temporal ordering. It describes how entities are arranged, without yet specifying how they interact.

It is important to distinguish configuration from structure. Spatio-temporal arrangement does not, in itself, imply the existence of causal relationships. Two entities may be positioned relative to one another without interacting, or without any transfer of matter, energy, or information occurring between them.

Given a set of entities in space-time, there are many ways in which they may be arranged, some of which are physically possible and others which are not. These possibilities are limited by basic conditions arising from the nature of entities and space-time itself. For example, two entities cannot occupy the same region of space-time simultaneously, and spatial separation limits the possibility of causal interaction. A list of typical configurational constraints is given in Appendix A and will be developed in future papers.

2.3 Structure

Structure arises when entities are connected through **causal relationships** (Ellis, 2012). These relationships involve the transfer of matter, energy, or information between entities (von Bertalanffy, 1968), as established in the previous paper in this series.

A structure may be understood as: *A configuration of components together with the causal relationships that connect them*.

Structure incorporates:

- **connectivity**, in that entities are linked through pathways of interaction
- **pathways of interaction**, along which transfers of matter, energy, or information can occur

A list of typical structural (causal) constraints is given in Appendix B and will be developed further in future papers.

Through these features, structure defines how components can potentially influence one another. It establishes the conditions under which processes may occur, and therefore provides the basis for the emergence of organisation over time.

It is important to note that structure does not necessarily imply recurrence. Entities may exhibit causal connectivity without forming repeating patterns. Structure therefore

represents a necessary but not a sufficient condition for the emergence of recurring organisation.

2.4 Organised Configuration

Organised configuration describes a configuration of entities arising from causal interaction between them. An organised configuration is therefore a special case of configuration more generally.

Structure may generate organised configurations, but does not necessarily do so. Structure associated with organised configuration is therefore a special case of structure more generally.

Structure and organised configuration are closely related but distinct. A configuration may or may not give rise to causal relationships between entities. Where such relationships exist, a network of causal connectivity forms structure. In turn, this structure may generate organised configurations as manifested spatio-temporal arrangements arising from causal interaction.

2.5 Static and Dynamic Structure

Structures do not all exhibit the same temporal characteristics. Some remain relatively unchanged over time, while others undergo recurring change.

A **static structure** is one in which both configuration and causal relationships persist with little or no change over the timescale of observation. In such cases, the arrangement of entities and the pathways of interaction remain effectively constant. Examples include crystalline solids or rigid frameworks.

Dynamic organisation, on the other hand, may occur in two distinct ways.

A **dynamic configuration** is one in which the configuration of entities changes in a recurring way over time. Although configurations vary, the variation itself exhibits identifiable recurrence or organisation. Examples are the hands of a clock and a swinging pendulum.

A **dynamic structure** is one in which the causal network between entities alters in a recurring way over time, while the entities remain overall causally connected in an organised way.

This distinction is important because change does not necessarily eliminate structure. Even where configurations or causal relationships are continuously transforming, structure may still be present (Prigogine & Stengers, 1984). It is within such arrangements that the possibility of recurring structure arises, forming one of the bases for information as developed in the following section.

Dynamic causal arrangements provide the basis for understanding processes as phenomena. A process may be understood as a sequence of changes in configuration or causal network that exhibits recurring organisation across time.

The concept of recurring dynamic causal networks raises questions that lie beyond the scope of the present paper. For example, why recurring dynamic causal networks may, but do not always, result in recurring dynamic configurations; and why causal networks themselves change in recurring ways over time. These questions point toward the roles of systems, environments, and constraints in the generation and maintenance of recurring organisation, and will be examined in later papers in this series.

2.6 Pattern

The term pattern may be used in more than one sense. Pattern may appear in artificial configurations (artificial patterns), in organised configurations (configurational patterns), or in causal networks (causal patterns). Configurational patterns, however, arise from causal patterns, since recurring organised configurations depend upon recurring causal organisation.

Truly “acausal” patterns may not actually exist in nature. Artificial patterns are explicitly generated through causal intervention by agents, while naturally occurring geometric or constraint-based regularities are most likely grounded in underlying causal organisation, even where the precise mechanisms involved remain unclear or unresolved.

Consider the example of closely packed spheres, which necessarily form a geometrical arrangement. Such regularities still depend upon causal processes, even where the resulting organisation appears geometric in form. Rather than constituting genuinely acausal organisation, these cases may be better understood as epistemic abstractions, idealised descriptions, or limiting cases realised through the causal intervention of agents. They are therefore more accurately interpreted as causally generated geometric regularities.

Consider also the example of the geometrical regularity of planetary orbits. If gravity were ultimately mediated through gravitons, then such patterns would arise through causal interaction in the transfer sense. Alternatively, if space-time were curved as described by Einstein’s General Relativity, then this curvature itself arises from the distribution of mass-energy. Curved space-time would therefore function as a causal constraint on planetary motion, shaping the possible trajectories available to orbiting bodies. In neither case is the underlying causal mechanism fully resolved. Gravitons remain hypothetical, while General Relativity does not explain the underlying mechanism by which mass-energy produces curvature. However, gravity may still be interpreted either as causal through transfer interaction or as the operation of causal constraint through the geometry of space-time. In neither case are recurring orbital

patterns entirely acausal. Orbital regularities therefore appear to arise through lawful constraint structures whose deeper causal basis remains unresolved.

Returning to the three types of pattern, artificial, configurational and causal, if artificial and configurational patterns are causally generated, then all recurring pattern is ultimately grounded in causality. The implication, therefore, is that pattern can exist only where causal relationships or causal constraints are present. In other words, recurrence requires causality. Without it, configurations and causal networks remain transient and non-recurring.

For this reason, unless otherwise stated, the term pattern in this paper refers to recurring causal organisation and its observable manifestations.

2.7 Information

Information arises where pattern occurs. It can therefore be understood as recurring causally organised pattern (Floridi, 2010).

This definition follows directly from the role of causality in the formation of structure and recurring configuration. As established earlier, recurrence is not possible without causal relationships capable of producing its reappearance in space-time. Information is therefore necessarily grounded in causally organised recurrence, whether expressed through recurring structure or recurring configuration.

It is important to distinguish information from structure and organised configuration more generally. Not all structures or organised configurations of entities constitute information. Both may exist transiently, without recurrence. Only where they exhibit repeatability do they qualify as information.

This definition is independent of meaning, interpretation, or observation (Ladyman et al., 2007). Information, as defined here, is an objective feature of physical reality. It does not depend on whether it is perceived, interpreted, or used by any observer. It provides therefore the basis for predictability and the emergence of more complex forms of organisation.

This distinction is important for maintaining a clear separation between:

- **information as physical structure;** and
- **information as interpreted or meaningful content**, which arises only within specific systems capable of processing and interpreting signals.

The latter is discussed below.

2.8 Information and Epistemic Processing

The definition of information developed in this paper is **ontological**, that is, as a feature of physical reality, independent of interpretation or observation. However, the term

“information” is also commonly used in an **epistemic sense**, referring to what is known, understood, or communicated. This usage introduces a different level of analysis, in which information is not merely present in the world, but is interpreted and processed by systems (Bateson, 1972; Floridi, 2010).

It is therefore necessary to distinguish clearly between information in the physical sense, and information in the epistemic sense.

Physical information consists of recurring structures or organised configurations that exist objectively in space-time. It is present whether or not it is observed, recognised, or used.

Epistemic information, by contrast, arises when physical information is detected, processed, and interpreted by a system. This involves additional processes, including perception or measurement, encoding and representation, and interpretation and evaluation. Through these processes, physical information gives rise to meaningful content, such as signals, messages, beliefs, or knowledge.

The distinction is crucial. Physical information does not depend on meaning, while epistemic information does. Meaning is not an inherent property of the former, but a result of interpretive processes within particular systems.

This paper is concerned with the ontological level. It establishes what information is in physical terms, prior to and independent of its interpretation. The processes by which systems detect, interpret, and use information will be addressed in later papers dealing with cognition, communication, and social organisation.

3. Summary: Pattern in Physical Reality

This paper has introduced a set of concepts that clarify how physical reality is organised into patterns, prior to the introduction of systems, environments, and constraints.

We begin with configuration: the disposition of entities in space-time. All physical reality is constituted by such arrangements, whether simple or complex, transient or enduring, recurring or not.

Where causal interactions occur between entities, involving transfers of matter, energy, or information, structure arises and organised configuration may also arise. Structure is the configuration of entities together with the causal relationships that connect them, enabling interaction and mutual influence. Organised configuration is the spatio-temporal arrangement that can result from these causal interactions.

Not all configurations or structures recur. Many are non-recurring, changing without forming repeatable arrangements. These constitute randomness, understood not as the absence of structure or configuration but as variation in them that does not lead to recurring pattern.

The concept of pattern may be understood as the observable manifestation of such recurrence. However, pattern does not exist in the absence of causality; it exists only where there is recurring causal structure or causally generated configurations.

A key implication follows from this: *recurring pattern requires causality* (Ellis, 2012). Patterns cannot recur unless there are causal processes capable of maintaining, reproducing, or re-establishing them.

When a recurring pattern exists, it constitutes information. Thus, it also follows that *information cannot exist without causality*. Information, in this framework, is not dependent on interpretation or meaning, but is an objective feature of physical reality.

The distinction between random and patterned configuration (one aspect ofinformation) is illustrated in Figure 2.

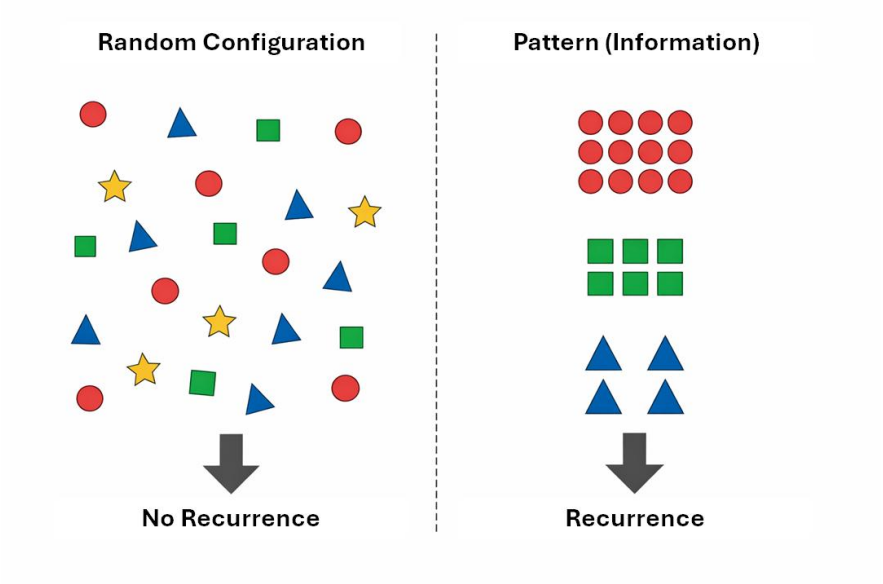

Figure 2. *Random and Patterned Configuration*

Together, these concepts form a coherent progression: randomness, configuration, structure, pattern, and information. This progression establishes what structure, pattern, and information are, without yet explaining why some structures recur while others do not. The mechanisms that lead to structure, including the roles of system–environment relations and constraints, will be developed in subsequent papers.

For now, the essential point is established: *Structure, pattern and information are not imposed by observers, but arise from causality in physical reality.*

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Appendix A – Configurational Constraints

Configurational constraints define the limits on how entities may be arranged in space-time. They determine what arrangements are physically possible. The following are preliminary definitions of key configurational constraint types. These will be developed further in a subsequent paper.

A1. Spatial Exclusion Constraint

A constraint whereby no two entities may occupy the same region of space-time simultaneously.

A2. Spatial Extension Constraint

A constraint whereby entities occupy finite regions of space-time and therefore possess size and shape.

A3. Topological Constraint

A constraint on the possible relational arrangement of entities, including connectivity, separation, and enclosure, independent of precise spatial distance.

A4. Continuity/Discreteness Constraint

A constraint arising from whether entities and arrangements are continuous or discrete, affecting the possible forms of arrangement and transformation..

A5. Kinematic Constraint

A constraint on how arrangements may change over time, including limits on motion and transition.

A6. Dimensional Constraint

A constraint arising from the dimensional structure of space-time, limiting possible arrangements and orientations.

A7. Boundary Constraint

A constraint whereby entities are spatially or temporally differentiated from their surroundings through boundaries.

Appendix B – Causal Constraints

Causal constraints regulate the occurrence, form, and persistence of interactions between entities. They operate at the level of structure and determine how causal processes unfold. The following are preliminary definitions of key causal constraint types. These will be developed further in a subsequent paper.

B1. Contiguity Constraint

A constraint whereby causal interaction between entities depends on their proximity in space-time.

B2. Enabling Constraint

A condition that permits or supports the occurrence of a causal interaction or process.

B3. Inhibiting Constraint

A condition that prevents, limits, or disrupts a causal interaction or process.

B4. Threshold Constraint

A constraint whereby a causal interaction occurs only when certain conditions or levels are reached.

B5. Rate Constraint

A constraint on the speed or frequency of causal interactions.

B6. Capacity Constraint

A constraint on the quantity or throughput of matter, energy, or information transfer.

B7. Directionality Constraint

A constraint on the direction of causal transfer between entities.

B8. Feedback Constraint

A constraint arising when the outputs of a process are reintroduced as inputs, influencing subsequent behaviour.

B9. Compositional Constraint

A constraint on how entities may be combined or assembled into larger arrangements.

B10. Coupling Constraint

A constraint on the strength and organisation of interactions between components.

B11. Stability Constraint

A constraint determining whether a structure persists or dissolves over time.

B12. Transformation Constraint

A constraint on how inputs are converted into outputs within a causal process.

Appendix C – Definitions

Some definitions from an earlier paper, *GST 02 The Ontological Foundations of General Systems Theory,* have been updated.

D2.13 – Configuration (Updated)

The spatial and temporal arrangement of entities with respect to one another, without necessarily implying interaction.

D2.14 – Structure (Updated)

The disposition of entities in space-time together with the network of causal relationships connecting them.

D2.15 – Static Structure (Updated)

A structure in which configuration and causal relationships persist with little or no change over the timescale of observation.

D2.16 – Dynamic Structure (Updated)

A structure in which configuration or causal relationships change in a recurring and organised way over time.

D2.17 – Randomness (Updated)

Randomness describes variation without recurring organisation. Randomness may occur in the spatio-temporal arrangement of entities or in the causal networks connecting them.

D2.18 – Information (Ontological) (Updated)

Recurring causally organised structure or recurring organised configuration.

D3.1 – Pattern

The observable manifestation of recurring causal organisation, whether structural or configurational. Unless otherwise stated, pattern refers to causal pattern.

D3.2 – Information (Epistemic)

Information as interpreted, processed, or understood by a system, arising from the detection and transformation of physical structure.

D3.3 – Spatio-temporal Arrangement

The disposition of entities relative to one another in space-time.

D3.4 – Organised Configuration

The spatio-temporal arrangement of entities arising from causal interaction between them.

D3.5 – Dynamic Configuration

A configuration in which the arrangement of entities changes in a recurring and organised way over time.

D3.6 – Artificial Pattern

A recurring configuration generated through the causal intervention of an agent.

D3.7 – Causal Pattern

A recurring causal network.

D3.8 – Configurational Pattern

A recurring configuration generated by causal relationships between components and constituting a specific manifestation of causal pattern.

D3.9 – Constraint or Condition

Constraints and conditions are complex causal networks delivering multiple enabling or inhibiting inputs to a system, thereby defining the range of behaviours in which the system can or cannot engage. The precise causal mechanisms involved are often unknown, distributed, or analytically impractical to specify directly, requiring simplification through the concepts of constraint and condition. These do not denote fundamentally different ontological categories, but different emphases within organised causal systems. In the case of constraints, the emphasis lies on the range of behaviours excluded or limited. In the case of conditions, it lies on the range of behaviours enabled or permitted.

Appendix D – Propositions

P3.1 – Configuration Possibility Proposition

A given set of entities may be arranged in multiple configurations within the configurational constraints of space-time.

P3.2 – Randomness Proposition

Randomness consists of variation in configuration or causal organisation that does not give rise to recurring pattern.

P3.3 – Structure Emergence Proposition

Structure arises when entities within a configuration become connected through causal relationships.

P3.4 – Structure–Interaction Proposition

Structure defines the pathways through which causal interactions and transfers of matter, energy, or information may occur between entities.

P3.5 – Organised Configuration Proposition

Organised configurations arise where causal interactions between entities produce recurring or stable configurational arrangements.

P3.6 – Recurrence–Causality Proposition

Recurring pattern requires causal organisation. Configurations can recur only where causal relationships or causal constraints exist that produce their reappearance in space-time.

P3.7 – Pattern Proposition

Pattern is the observable manifestation of recurring causal organisation, whether expressed structurally or configurationally.

P3.8 – Information Proposition

Information consists of recurring causally organised structure or configuration.

P3.9 – Structure–Information Distinction Proposition

Not all structure or organised configuration constitutes information; only recurring structure or organised configuration qualifies as information.

P3.10 – Dynamic Structure Proposition

Structure may persist through recurring configurational or causal change as well as through static continuity.

P3.11 – Information Objectivity Proposition

Information, as recurring causally organised pattern, exists independently of observation, interpretation, or meaning.

P3.12 – Ontological–Epistemic Distinction Proposition

Epistemic information arises through the interpretation of physical information by a system and is distinct from information as an objective feature of physical reality.

P3.13 – Configurational Dependence Proposition

Configurational patterns depend upon underlying causal organisation, even where such organisation is not directly observable.