Causal Assembly Theory:

Assembly and Disassembly as Causal Processes

John A Challoner, November, 2026

Abstract

How do separate entities become components of systems, and how do those systems persist, change or break down? Causal Assembly Theory addresses these questions by relating organised component participation to physical interactions, transfers and constraints. Building upon Foundational Causality, it treats assembly and disassembly as causal processes within a source–transfer–recipient account of matter, energy and physically embodied information.

The paper distinguishes assembly from collection and configuration, and separates the processes establishing organisation from the interactions and configurational or energetic constraints maintaining it. It examines how transfers, temporary incorporation and component replacement allow processes to continue, and how overlapping incorporation may help maintain physical coupling and configuration. System boundaries and identity are explained through organised participation and continuity through change.

Maintained organisation can connect component capabilities to establish capabilities to produce or accept transfers that the components do not possess separately. This provides the paper's account of causal emergence and its distinction between systems and pre-systemic assemblies. Recursive assembly connects organisation across levels, while system activity can modify the components and relationships supporting later processes.

Capabilities can remain latent until suitable inputs or conditions arise. Their sources include unused component capabilities, alternative configurations and configurationally entrained components. Activation can propagate through internal transfers, supporting, modifying or undermining organisation. Examples illustrate particular mechanisms, while broader hypotheses identify relationships for further investigation. The theory provides a common causal account linking familiar systems concepts and a basis for investigating their physical mechanisms and interrelationships.

1. Purpose and Scope

Causal Assembly Theory explains how entities become organised as components of systems, how that organisation persists or changes, and how it breaks down. Its purpose is to ground these features of systems in the mechanisms described by

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contemporary physics, identifying the interactions, transfers and constraints through which organisation is established and maintained. In doing so, it provides a common causal foundation for understanding familiar systems concepts, including boundaries, processes, persistence, emergence and hierarchical organisation.

Describing entities as joining, combining or breaking apart identifies a change but does not necessarily explain it. A causal explanation must identify what establishes or ends their participation as components, what maintains their relationships, and how those relationships affect what the resulting assembly can do. These questions apply to atoms forming molecules, cells becoming organised into tissues, people establishing organisations and many other forms of assembly. The mechanisms differ between cases, but the same general questions can guide their investigation.

The account builds upon *Foundational Causality* (Challoner, 2026), in which causal relationships involve transfers of matter, energy or physically embodied information from sources to recipients. Assembly and disassembly are examined within that account, together with the physical interactions and configurational and energetic conditions through which organisation is established, maintained or disrupted. The theory connects these mechanisms with system formation and behaviour without proposing an additional fundamental physical force or a separate form of causality.

The name requires clarification because Assembly Theory is already associated with the work of Leroy Cronin, Sara Imari Walker and their collaborators. That research examines how objects can be constructed from simpler constituents and relates their construction histories to complexity, selection and evolution (Sharma et al., 2023). The present paper addresses a different, complementary question: how causal processes establish and change the organisation through which entities participate as components of more extensive entities. It is therefore termed Causal Assembly Theory. Throughout this paper, “assembly” and “disassembly” refer to the processes examined here unless otherwise stated.

The paper first establishes the relationships between causality, transfer, configuration, assembly and disassembly. It then examines how assemblies form and persist, distinguishing the processes that establish organisation from the interactions and constraints that maintain it. From this foundation, it develops an account of connected processes, system-level capabilities, recursive organisation and latent causal potential. These mechanisms are then used to explain how systems can retain boundaries and identity despite component turnover, develop reliable activity, and gain or lose capabilities as their organisation changes.

The scope includes physical, chemical, biological, social and epistemic examples. Social and epistemic processes are treated as physically instantiated: communication involves physical transfers, while knowledge and explanations are represented through

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cognition and external records. Applying a common causal account does not imply that all these domains have identical mechanisms. Established examples illustrate particular mechanisms; broader hypotheses about their application and combination are identified for further investigation.

2. Causality, Transfer, Assembly and Disassembly

2.1 Source, Transfer and Recipient

In the account developed in *Foundational Causality* (Challoner, 2026), a causal relationship involves a physical transfer from a source to a recipient:

Source A → transfer C → recipient B

The transfer may comprise matter, energy or physically embodied information. A heated object can transfer energy to another object, while a person can communicate information through speech, writing or another physical medium.

Source and recipient describe roles within a particular relationship. The same entity may receive one transfer and produce another. Connected causal relationships can therefore form processes in which outputs from some entities become inputs to others.

What is transferred need not be only a small part of the source. It may be a component, a lower-level constituent or the entire source entity. These possibilities connect causal transfer with assembly and disassembly.

2.2 Collection, Configuration and Assembly

Before examining that connection, three concepts need to be distinguished.

A collection consists of entities considered together. They need not interact or occupy any particular arrangement. All the red cars in a car park constitute a collection because they have been selected according to a shared characteristic.

A configuration describes the arrangement of entities in space and time. Parked cars occupy particular positions and orientations relative to one another. Entities passing a location at different times also possess temporal relationships. A configuration may be momentary, persistent or changing.

Configuration can affect what entities can do without making them components of an assembly. Closely parked cars may obstruct one another's exit. Rearranging them can permit movement without changing the cars themselves. Similarly, three objects arranged in a triangle possess a relationship that none possesses individually, but that arrangement alone does not establish an assembly or an emergent causal capability. Configuration can therefore enable or constrain existing capabilities without changing the intrinsic properties of the participating entities.

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Assembly occurs when interactions establish the organised participation of entities as components of a more extensive entity. A bolt placed beside a machine has acquired a new position relative to it. Insertion and fastening establish its participation as a component.

The distinction can be summarised as:

Collection → configuration → assembly

This is a conceptual progression, not a sequence that must always occur as three separate stages. A collection identifies entities considered together; a configuration specifies their arrangement; assembly establishes their organised participation as components.

2.3 Assembly as a Process and an Entity

The word assembly can refer both to an activity and to its result. The following definitions distinguish these meanings:

- Assembly is a causal process through which previously separate entities become organised as components of a more extensive entity.
- An assembly is an organised entity comprising two or more components, formed or subsequently modified through assembly processes.

The participating entities need not initiate the process themselves. An agent may position and fasten a bolt, while physical interactions can incorporate an atom into a molecule. A person may become a component of a social organisation through communication, agreement and changes in responsibilities and relationships. The mechanisms differ, but each establishes organised component participation.

Disassembly concerns the complementary change:

- Disassembly is a causal process through which one or more entities cease participating as components of an assembly.

Neither assembly nor disassembly is defined by spatial movement alone. Entities already near one another can become assembled when suitable interactions establish their component relationships. Conversely, components can cease participating before moving apart.

These definitions concern the establishment or loss of organisation. They do not require the processes that form an assembly to continue maintaining it. Formation and maintenance are examined separately in Section 3.

2.4 Levels of Transfer and Whole-Entity Assembly

Transfers can occur at different organisational levels:

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- Whole-entity transfer: the entire source entity participates in the transfer and becomes incorporated with the recipient into a more extensive assembly.
- Whole-component transfer: an entire component is transferred from a source assembly.
- Lower-level component transfer: what is transferred forms part of a component of the source assembly.

These descriptions depend upon the level being examined. A whole component of one assembly may itself contain components, while the assembly containing it may be a component of something larger. The transferred entity may therefore itself be an assembly or a system.

In whole-entity transfer, incorporation establishes a new component role. The transferred entity need not lose its identity or internal organisation. An atom can become part of a molecule, and an assembled mechanism can become part of a machine, while retaining relevant features of their existing organisation. The resulting relationships can enable interactions that were previously unavailable, while restricting others. Assembly can therefore change what the participating entities can do without necessarily changing their internal organisation.

Where two previously separate entities A and B become assembled, the relationship can be viewed as A joining B or B joining A. Exchanging the transferred-entity and recipient roles provides alternative representations of the same assembly:

$$A + B \rightarrow AB$$

Here, AB denotes the resulting organised entity. No third, pre-existing recipient is required. Both A and B become its components. These alternative perspectives do not imply that the physical direction of any particular transfer is reversed.

Whole-entity transfer consequently does not require an additional fundamental category of causality. The source–transfer–recipient relationship accommodates the incorporation of an entire entity. Nor does incorporation necessarily require that entity to move through space: interactions can establish its component role where it is already situated.

When a component or lower-level constituent leaves an existing assembly, its release constitutes disassembly relative to that source. If it becomes incorporated elsewhere, assembly occurs relative to the recipient. Release does not guarantee subsequent incorporation, however. The released entity may remain in the environment.

2.5 Partial and Complete Disassembly

Disassembly can affect some component relationships while leaving others intact.

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In partial disassembly, an assembly loses components or connections while continuing to exist:

$$ABCD \rightarrow ABC + D$$

The consequences depend upon the roles affected. Some capabilities may remain, while others are altered or lost. Component membership, causal capability and continued identity are therefore related but distinct questions.

In complete disassembly, sufficient organisation is lost for the previous assembly to cease to exist as that entity:

$$AB \rightarrow A + B$$

Complete disassembly does not require destruction of the former components or removal of every relationship between them. A larger assembly may separate into smaller assemblies:

$$ABCD \rightarrow AB + CD$$

AB and CD can retain their internal organisation while losing the relationships through which they participated in ABCD. “Complete” therefore refers to the loss of the specified assembly, not to the disappearance of organisation at every level.

Configuration can also remain after disassembly. Parts of a disconnected pipe joint may remain aligned and close together even though they no longer maintain the sealed connection. Their positions alone do not preserve the previous assembly.

2.6 Temporal Relationships between Disassembly and Assembly

Where an entity passes from participation in one assembly to participation in another, three temporal relationships can be distinguished.

- Prior disassembly. Participation in the source ends before incorporation into the recipient begins. An intervening period may occur during which the entity participates in neither assembly. A component removed from one machine and later installed in another illustrates this relationship.
- Concurrent disassembly and assembly. Incorporation into the recipient begins as participation in the source ends. At the level of description concerned, there is no intervening gap or overlap. A component passed directly between two retaining mechanisms may approximate this relationship.
- Subsequent disassembly. Incorporation into the recipient begins before participation in the source ends. The resulting overlap may be brief or extensive. For example, an individual may undertake organised responsibilities within a new institution while retaining responsibilities in the previous one, before eventually leaving it.

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These categories describe the timing of organisational changes, rather than additional fundamental forms of causality. Joining and leaving can themselves take time as relationships develop or cease. Overlap is possible where the component roles and relationships are compatible.

2.7 Internal Organisation and External Component Roles

A transferred entity may itself be an assembly. Its internal organisation must therefore be distinguished from its role as a component of another entity.

An assembled mechanism can be removed from one machine and installed in another without disassembling its own parts. Its external component role changes while its internal organisation persists.

Where that internal organisation depends upon continued support or causal coupling, incorporation into the recipient before release from the source may help preserve it. The recipient establishes the necessary interactions before the source interactions end. Preservation nevertheless depends upon the particular interactions and conditions, rather than upon temporal overlap alone.

Initial preservation may also be temporary. A recipient can subsequently transform or disassemble an incorporated entity, retaining some constituents and releasing others. Changing membership therefore does not require immediate internal disassembly, but neither does it guarantee that the transferred entity will remain intact.

These distinctions allow us to examine separately what is transferred, when its component roles change, and what happens to its own organisation. The next section considers the physical mechanisms that establish and maintain those relationships.

3. Configuration, Formation and Maintenance

3.1 Formation and Maintenance Are Different Questions

Explaining how an assembly forms does not necessarily explain how it persists. The processes that establish its organisation may cease, while other interactions and constraints maintain the resulting relationships.

For example, fastening mechanical parts requires movement and an input of energy. Once fastening is complete, contact interactions, friction and the arrangement of the parts can restrict their subsequent movement. The fastening operation need not continue.

In other cases, interactions that establish organisation also contribute to maintaining it. Formation and maintenance are therefore different causal roles, even where their mechanisms overlap. We can investigate them through two questions: *What established the organisation?* and *What maintains it?*

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Three contributions to formation can be distinguished: environmental circumstances that permit suitable encounters, physical interactions that establish component relationships, and agentic activities that direct assembly. These contributions can operate together.

3.2 Environmental and Configurational Enablers

Assembly requires suitable entities to encounter one another under conditions permitting the necessary interactions. Their positions, orientations, movements and timing affect whether this occurs.

The concentration of compatible entities can influence the frequency of suitable encounters. Environmental flows may bring entities together, boundaries may retain them within a region, and surfaces or channels may direct their movement. Timing also matters: entities capable of interacting must be available together. Temperature, pressure and other conditions can affect which interactions are possible.

These circumstances do not necessarily establish assembly themselves. They provide configurational enablers or constraints affecting opportunities for assembly-producing interactions. Bringing many compatible entities together can increase opportunities without guaranteeing incorporation.

Environmental circumstances can also inhibit assembly. Potential components may be too dispersed, incorrectly oriented or separated by obstacles. A change in configuration can therefore permit interactions that were previously prevented, without changing the participating entities' intrinsic properties.

3.3 Physical Interactions Establish Component Relationships

Physical interactions establish the relationships through which entities participate as components of an assembly. A suitable configuration permits these interactions, but configuration alone does not establish organised participation.

The relevant interactions differ between cases. Contact forces, friction and adhesion can contribute to mechanical assembly. Electromagnetic interactions underlie chemical bonding and many interactions between larger material structures. Chemical assembly therefore does not require a fundamentally separate form of physical causality.

Assembly need not involve direct contact or fixed relative positions. Gravitational and electromagnetic interactions can maintain organised relationships between spatially separated or moving components. Nor must components remain permanently attached: their participation may involve intermittent interactions and exchanges with other components or the environment.

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The fundamental interactions have different roles. Electromagnetism provides binding in atoms and molecules, while the residual strong interaction binds protons and neutrons within atomic nuclei. Gravity is particularly important in astronomical assemblies. Weak interactions transform participating particles in processes that can contribute to formation or breakdown; they should not be treated as another general binding mechanism. (CERN, n.d.)

These interactions can establish, maintain, transform or disrupt organisation. Their contribution depends upon the entities involved, their states and the conditions under which they interact.

3.4 Energy Transfers and Energetic Constraints

Physical interactions and energy transfers can allow initially separate entities to enter a bound arrangement. Energy released during formation may pass to other entities or the surroundings through radiation or other interactions. At atomic and nuclear scales, this provides examples of assembly whose formation process need not continue throughout its existence (Feynman et al., 1965).

Not every formation pathway simply proceeds towards a lower-energy arrangement. Energy may first be needed to cross a barrier before the resulting assembly can form. Crossing that barrier and the overall energy difference between the initial and final arrangements are separate matters: formation can require an initiating input even where it subsequently releases energy.

An assembly may also occupy a local energy minimum above other possible arrangements. It can persist because leaving that state requires crossing a further barrier (Carr et al., 2016). Quantum tunnelling can permit some transitions through barriers, so their presence does not make escape impossible(Feynman et al., 1965).

Once established, a bound assembly need not receive continuing net energy input simply to remain bound. Where the separated state has higher energy than the bound state, separation requires sufficient energy to be supplied through an appropriate interaction. Other assemblies require continuing inputs to maintain their organisation or replace losses.

Disassembly can consequently require energy, release energy, or involve an initiating input followed by energy release. Explaining formation and breakdown requires attention both to energy differences and to the interactions through which the changes can occur.

These relationships provide a connection with energy landscapes, which offer a way to represent possible configurations, persistent states and barriers between them. Their fuller application is considered among the theory's future developments.

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3.5 Agentic Contributions to Assembly

Agents can direct assembly by selecting entities, bringing them into suitable configurations and establishing relationships between them. Mechanical construction provides a familiar example. Organisms can also collect and organise materials into nests or other structures.

Agentic action does not introduce a separate fundamental form of causality. An existing organised entity directs physical transfers and interactions towards an outcome. Its activities can establish conditions that would otherwise be absent or unlikely.

Human agents can establish organisations through communication, agreement and coordinated action. Cognitive activity can likewise organise recognised entities and propositions into explanations or theories. These activities are physically instantiated, although the relationships represented within an explanation must be distinguished from physical interactions between its representations.

Existing assemblies can therefore contribute to the formation of further assemblies. This includes deliberate construction, but also biological processes that produce, transport and position materials without requiring conscious intention.

3.6 Interactions and Constraints Maintaining Organisation

Maintenance can involve continuing physical interactions, configurational constraints, energetic constraints or combinations of these.

Configurational constraints can restrict movement because components obstruct or interlock with one another. Such retention depends upon physical interactions between the structures involved. Energetic constraints restrict changes where the energy needed for separation or disruption is not available through the relevant interactions under prevailing conditions.

Where one component’s state or behaviour causally constrains, enables or influences another, their relationship can be described as causal coupling. Coupling need not involve continuous transfer, operate in both directions or connect every pair of components directly. Components may instead participate in a network of direct and indirect relationships.

Some assemblies require extensive continuing activity. Organisms acquire materials, maintain internal conditions and repair or replace components. Social organisations depend upon communication, participation and coordination. Other structures persist with comparatively little ongoing activity because their binding and configurational constraints remain effective.

Persistence therefore does not require permanence, fixed component membership or continuous activity by every component. It requires sufficient continuity of the

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organisation through which the entity persists. Changes to the interactions or constraints maintaining that organisation can permit modification or disassembly.

3.7 Overlapping Transfers Can Help Maintain Configuration

Overlapping incorporation can contribute to maintenance in two distinct ways.

First, as explained in Section 2.7, it can help preserve a transferred entity's internal organisation. Recipient interactions provide necessary support before source interactions end.

Second, it can maintain a physical connection between the source and recipient. Suppose a component C becomes incorporated into B before its participation in A ends. During the overlap, interactions through C can couple A and B. Where those interactions constrain their relative movement, they can help maintain the configuration of A and B themselves.

If such connections occur repeatedly, with sufficient continuity between them, successive temporary couplings may help sustain a system's configurational structure despite continuing transfers. A persistent overlapping connection represents an extreme case of the same possibility.

This is a hypothesis about how transfers can contribute to structural maintenance. Its application depends upon whether the particular interactions provide the required coupling and whether that coupling remains sufficiently continuous. Temporal overlap alone does not establish configurational restraint.

3.8 Formation and Maintenance Across Domains

The preceding distinctions can be applied across different domains while identifying the particular mechanisms involved.

- In physical assembly, closing a zip brings its teeth into an interlocking arrangement. Movement of the slider establishes that arrangement, while the shapes of the teeth and their contact interactions subsequently resist separation. The slider need not remain in motion to keep the zip closed.
- In chemical assembly, a salt crystal can grow as water evaporates from a solution. Evaporation increases the concentration of dissolved ions, creating conditions favourable to crystal growth. Interactions incorporate ions into an ordered lattice, which can subsequently persist through electrostatic interactions after evaporation ends.
- In biological assembly, cells divide, grow and become organised into tissues during the development of a leaf. The resulting structure is maintained through continuing cellular activity, supplies of water and nutrients, and repair or replacement of cellular components. The plant also incorporates new matter

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into growing roots and shoots while losing or replacing existing structures. Formation, maintenance and further growth can therefore occur together.

- In social assembly, residents may establish a flood-response group by agreeing responsibilities, communication arrangements and procedures. Maintenance subsequently depends upon continuing participation, current contact information, training and coordination. The founding meeting need not be repeated, but the relationships it establishes must remain effective. Residents independently watching the same river do not form such an organisation merely through shared location or concern.
- In epistemic assembly, an investigator may relate rainfall records, measured flows and evidence of groundwater infiltration through propositions explaining why a sewer becomes overloaded. Cognitive activity constructs the explanation, while memory and written or digital records support its retention. New evidence may lead to the addition, revision or removal of propositions while much of the explanation remains intact. The explanatory relationships are represented through physical activity and records; they are not physical causal interactions between abstract propositions.

These examples show how the same questions reveal different mechanisms: what establishes organisation, what maintains it, and what changes permit its modification or breakdown? The resulting organisation, in turn, affects what the assembly can do. The next section examines those capabilities and the processes through which they are realised.

4. Processes, Systems and Changing Capabilities

4.1 Causal Capability and Its Realisation

An assembly is an effect of preceding causal processes, but it can subsequently participate in further processes as a source or recipient of transfers. A pump, for example, is assembled from components and can then receive energy and transfer water. Its formation and operation are different processes.

What an assembly can do depends upon its components, their properties and their organisation. The components of a pump must be suitably arranged and connected for an energy input to produce water flow. Merely collecting the same parts together, without the necessary organisation, would not provide that capability.

A capability need not be exercised continuously. A stationary pump may remain capable of moving water while awaiting an energy supply, available water and an unobstructed flow path. This distinguishes causal potential, meaning what an entity can do under suitable conditions, from realised causal activity, in which the relevant interactions and transfers occur:

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Components and organisation + suitable inputs and conditions → process → effects and output transfers

Receiving an input does not guarantee a particular output. The organisation and other conditions needed to produce it must also be present. Conversely, the absence of an output does not necessarily indicate loss of capability: a required input may simply be missing.

4.2 Connected Processes and Temporary Incorporation

A process comprises connected causal interactions. These can form linear, converging, branching or cyclic pathways through which the process receives inputs from, and produces outputs to, its environment.

Within a system, an entity may pass through successive components, becoming temporarily incorporated, transformed and released. The products of one stage can become inputs to another.

An enzyme-catalysed reaction illustrates temporary incorporation. An enzyme is a biological catalyst, and the substrate is the molecule upon which it acts. The substrate binds temporarily to the enzyme, becoming a subcomponent of the resulting assembly. Their interaction facilitates a chemical change, after which the products separate and the enzyme can participate again.

Within a connected sequence, a released product may become a temporary subcomponent elsewhere and undergo further transformation. The organisation connecting these stages can remain while successive incoming entities pass through them.

Such activity need not follow a single sequence. Several inputs may converge upon a subsystem, outputs may follow different pathways, and feedback may return outputs to earlier stages. Transfer, transformation, assembly and disassembly can therefore operate throughout a causal network. These are useful descriptions of operations, rather than an exhaustive set of independent elementary mechanisms.

Processes can also produce, modify or remove the components and relationships through which later activity occurs:

Existing organisation → causal activity → organisational change → changed possibilities for subsequent activity

A newly produced component may participate immediately or remain available for later use. Operation can consequently change both current activity and latent causal potential.

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4.3 Representing Causal Processes

The networks described above can be represented by following either processes or transfers. In the PTP representation, processes are connected by transfers. In the TPT representation, transfers are connected by processes (Challoner, 2026). Assembly, transformation and disassembly can be included as processes within either representation.

Where operations, connections and enabling conditions can be specified, it may be possible to represent a process as a causal algorithm. This describes which operations occur, how they are connected and the conditions under which particular pathways are followed. It may include branching, repetition and feedback.

A simplified expression is:

Assembly → transformation → disassembly → transfer to a subsequent process

A fuller representation would identify the participating entities, transfers and conditions at each stage.

The algorithm describes the physical process; it does not perform it. Writing an assembly operation does not assemble anything. The actual event occurs through physical interactions and transfers.

If activity changes the components or relationships supporting subsequent operation, an accurate representation must reflect those changes. The process does not automatically rewrite its description. The description must be revised when necessary.

Algorithmic representation is therefore a proposed possibility for suitable cases, rather than a requirement that every physical process must be expressible as an algorithm.

4.4 Emergence and the Distinction between Assemblies and Systems

Emergence has been defined in different ways, including accounts concerned with novelty, irreducibility, and weak and strong emergence (Bedau, 1997; Corning, 2002). This paper adopts a specific causal meaning:

Causal emergence occurs where an assembled entity possesses a capability to produce or accept transfers that depends upon its maintained organisation and is not possessed by its components acting separately.

Assembly can connect component capabilities so that their processes operate together when suitable inputs and conditions arise. An output from one component becomes an input to another, allowing further interaction or transformation. The resulting system-level transfer depends upon the connected organisation, rather than upon any component acting independently.

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Temporary incorporation can help realise this capability. Incoming entities become temporary subcomponents, undergo transformation and pass to subsequent stages. The organisation connecting the stages persists between successive inputs, maintaining the capability even when it is inactive.

The same outcome might occasionally occur through encounters between entities that do not form a persistent assembly. In that case, the necessary relationships must come together on each occasion. An assembled system maintains those relationships, preserving the capability between occasions of use. The distinction is therefore between an outcome occurring and an organised entity possessing a continuing capability.

Organisation may also make an existing process more reliable by retaining participants or directing transfers. Investigating emergence requires identifying which capability the assembled organisation maintains and how it depends upon those relationships. Configurational novelty alone does not establish such a capability.

This provides the terminology used here:

A system is an organised assembly with a maintained emergent causal capability.

A pre-systemic assembly possesses organisation but does not sustain an emergent causal capability.

Both may accept inputs and produce outputs. The distinction concerns whether the maintained organisation supports a capability unavailable to the components acting separately.

A system may support several processes, which can share components. Some may be active while others remain latent. Its organisation and capabilities therefore cannot be identified solely with the process currently being observed.

4.5 Recursive Assembly and Organisational Levels

An assembly can itself become a component of a more extensive assembly. Entities A and B may form C, while D and E form F; C and F may then become components of G:

$$A + B \rightarrow C$$

$$D + E \rightarrow F$$

$$C + F \rightarrow G$$

C and F need not lose their internal organisation when incorporated into G. Each is an assembly relative to its own components and a component relative to G. This recursive participation provides a causal account of nested organisation, a familiar feature of complex systems (Simon, 1962).

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An additional stage of assembly does not necessarily establish another emergent capability. Several stages may be needed before the required organisation develops. An organisational level identifies how assemblies participate as components of larger assemblies; a level of emergent capability identifies what the resulting organisation can produce or accept that its components cannot separately.

These distinctions provide a basis for investigating ontological hierarchy through physical organisation and its consequences. They do not assume that every increase in nesting establishes a new level of emergence.

The levels are physically connected through transfers. Processes within components can jointly produce an output from the system as a whole, which may become an input to another system. Conversely, inputs received by a larger assembly can pass to its components and activate processes within them.

Existing assemblies can also contribute to further assembly by producing or supplying components, energy or information. A cell, for example, produces and brings together molecules needed to construct cellular structures. Recursive development can therefore involve both incorporation of existing assemblies and processes that establish new ones. It does not imply that organisational complexity must continually increase.

4.6 Latent Causal Potential

A system's current activity reveals only the capabilities being exercised under the conditions observed. Other physically embodied capabilities may remain inactive.

Latent causal potential comprises capabilities that are not currently realised because necessary inputs or enabling conditions are absent, or because constraints inhibit their operation.

A latent process is a physically retained possibility for activity, rather than an interaction currently occurring. Its physical basis lies in the properties of components and their relationships, rather than in activity occurring continuously.

This distinction matters when conditions change. A system may respond to an unfamiliar input through capabilities that its usual operation has not revealed. Their activation can maintain the system, alter its behaviour or disrupt its organisation.

4.7 Sources of Latent Potential

Existing components can possess capabilities beyond those exercised in their current roles. Some can operate when a suitable input arrives without substantial reorganisation. Others require changes in component arrangements or relationships.

The latter possibility is termed alternative configurational potential: existing components can assume different physically accessible configurations through which different interactions become possible.

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Moonlighting proteins illustrate how one physical entity can perform different functions under different conditions (Jeffery, 1999). Part of the bacterial protein RfaH, for example, can fold into two different shapes. In one shape it can bind to part of the cell's protein-making machinery and help that machinery produce proteins (Burmann et al., 2012). This change of shape enables a different interaction by the same protein.

Additional potential can enter an assembly through retained entities. A Configurationally Entrained Component, or CEC, is incorporated and retained without participating in the interactions constituting the specified focal organisation. Its capture and retention nevertheless involve physical interactions.

Fluid trapped within a crystal provides an example. The fluid does not form part of the crystal lattice, although the containing physical assembly includes both the lattice and the retained fluid. The fluid possesses capabilities of its own, some of which may remain inactive.

CEC status is therefore relative to the organisation being examined. CECs provide one source of additional potential; they are not required to explain all latent capabilities.

4.8 Activation through Inputs

Inputs provide a principal route through which latent potential becomes active. Matter, energy or physically embodied information may supply something an inactive process requires, change component relationships or remove an inhibition.

Activation can depend upon the type, amount, timing and combination of inputs. Several inputs together may permit activity that none permits alone. Reduction or cessation of an input can also allow activity where that input previously maintained inhibition.

The response depends upon both the transfer and the receiving organisation. The same input can activate a capability in one system and have little effect in another because their components, relationships or constraints differ.

An input to the system as a whole comes from its environment. Within that system, however, an output from one component can become an input to another. Activation can therefore occur through internal transfers without a fresh external input at that moment:

Existing capability + suitable input and enabling conditions → realised process → effects and output transfers

Activation must also be distinguished from creating a capability. An input can realise a capability already present, or cause assembly, transformation or reorganisation that establishes a new one. These are related but different changes.

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4.9 Retention and Inheritance of Potential

When an assembly becomes a component of a larger assembly, retained components and relationships can carry latent capabilities into that larger entity. CECs can likewise become nested through recursive incorporation.

Retention does not guarantee continued access to every capability. Incorporation can restrict which inputs reach a component, which entities it can encounter or which configurations it can assume. A capability can remain physically embodied while becoming harder to activate.

Conversely, component loss can remove latent capabilities without immediately disrupting current processes. Maintaining present activity and preserving possible responses to future circumstances are therefore different matters.

Adaptability depends both upon possessing relevant capabilities and upon being able to activate and coordinate them when required. The consequences of losing such potential are examined in Section 5.

4.10 Propagation of Activation

An activated process can produce transfers that become inputs to other components and activate further capabilities:

Initial input → activation → internal transfer → further activation → wider change

For example, one process may remove an inhibition elsewhere, permitting another process to operate. Its outputs can then affect further components.

Propagation depends upon the necessary connections, inputs and conditions. A change may remain local, be suppressed or spread across several organisational levels. It can involve existing pathways, reconfiguration, CEC activity or combinations of these.

A relatively small initiating input may consequently lead to substantial change where the system already contains the organisation and resources supporting that response. The initiating input need not itself supply all the energy or material involved in the subsequent activity.

Retained fluid illustrates one possible disruptive mechanism. Under suitable conditions, pressure within a fluid inclusion can deform or fracture its quartz host (Bodnar et al., 1989). This supports a particular physical mechanism. Explaining wider propagation requires tracing the further interactions and transfers through which the disruption spreads.

4.11 Supporting and Undermining Effects

Bogdanov's discussion of complementary relationships and systemic contradictions recognised that processes within an organised complex can support its organisation or

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undermine it (Bogdanov, 1980, pp. 136–140). Activation of latent potential provides a possible physical explanation of how changed inputs or internal activity can bring these different effects into operation.

An activated capability may maintain relationships, enable repair or provide an alternative pathway. It may instead interrupt required transfers, consume resources needed elsewhere or initiate disassembly. Some effects may make little difference to the assembly's continued existence.

These consequences depend upon the entity, organisational level and timescale considered. Disassembling a component can contribute to maintaining a larger system, while activity preserving one component can undermine its containing assembly.

Systems can constrain disruptive activity by restricting inputs, retaining or removing particular entities, or inhibiting interactions. A protective boundary alone does not establish that any particular capability is controlled; the relevant mechanisms must be identified.

The account thus connects assembly history, present organisation and future possibilities. Assembly establishes relationships and can retain additional entities. These embody capabilities, inputs bring some into operation, and their activity can modify the organisation supporting later processes. Section 5 examines how these connected mechanisms explain familiar features of systems.

5. What the Theory Explains

The mechanisms developed in the preceding sections connect several familiar systems concepts. Assembly establishes organised participation; interactions and constraints maintain it; transfers realise capabilities; and continuing activity can change the organisation supporting subsequent processes.

This section examines what those relationships explain, particularly where systems grow, exchange components, retain their identity or respond differently to changing circumstances.

5.1 Progressive Formation, Growth and Component Replacement

An assembly can develop through successive additions:

$$A + B \rightarrow AB$$

$$AB + C \rightarrow ABC$$

Each addition builds upon organisation already established. There need not be a single event at which the complete assembly comes into existence.

Further assembly can occur while existing processes continue. A crystal, for example, can grow as additional atoms or ions become incorporated into its lattice. The additions

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extend its existing organisation rather than requiring the crystal to be reconstructed. Progressive formation describes how an assembly develops through successive stages; growth describes extension of an entity that already exists.

Components can also be replaced. An incoming component must establish the relationships and perform the role required within the assembly. Replacing a valve in an irrigation network, for example, requires suitable connections and the ability to control the relevant flow. Substituting an entity of approximately the same size would not necessarily preserve the process.

The consequences of replacement depend upon the role affected. Alternative components or pathways may allow activity to continue during an interruption. In other cases, loss of a single connection can stop an essential process. Replacement can therefore involve a gap, a concurrent handover or overlapping participation, according to what the remaining organisation can sustain.

Growth and replacement show why assembly need not be confined to initial formation. Continuing assembly and disassembly can extend, maintain or modify an existing system.

5.2 Process Persistence despite Changing Components

An open system can persist while exchanging matter and energy with its environment (von Bertalanffy, 1950). Causal Assembly Theory explains how this can occur through continuity of organisation despite changing participation.

Incoming entities may become temporary components, undergo transformation and leave, while the organisation connecting successive stages remains. The enzyme example in Section 4.2 illustrates this distinction: substrates and products change, while the enzyme remains available for further activity. In a connected process, products released from one stage can become inputs to another.

Continuing activity therefore need not require the same material entities to occupy every role throughout the process. It requires sufficient continuity of the components, relationships and constraints through which successive inputs are received, transformed and released.

This does not mean that every exchange preserves the system. A transfer may remove a necessary component, disrupt a connection or introduce an entity that changes existing interactions. Persistence must be explained by identifying what maintains the relevant organisation through those exchanges.

5.3 Process Boundaries and Organised Participation

A boundary distinguishes the organisation of a specified process or system from its environment. That distinction cannot be established from location alone.

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Some entities remain as components, others participate repeatedly, and others become temporarily incorporated before leaving. External entities can supply inputs, receive outputs or otherwise influence the process without becoming components of its organisation.

A river channel provides an example. Its banks and bed direct the flow while water enters, passes through and leaves. Surrounding land may supply runoff without becoming part of that organised flow. The channel structures and passing water participate in the process itself, whereas the surrounding land acts as an external source.

A water molecule can therefore participate temporarily and later leave without the process boundary following it into the environment. Changing component membership need not destroy the broad spatial and temporal continuity of the channelled flow. The boundary changes when the extent of that organisation changes, as when the river overtops its banks.

The same causal perspective distinguishes interactions within an organisation from transfers crossing its boundary. Internal interactions connect participating components, while transfers crossing the boundary connect them with environmental sources or recipients. Temporary and overlapping participation can make this distinction change over time or remain partly graded. Spatially dispersed components may remain organised through physical communication and other transfers, so a boundary need not be a single enclosing surface.

Neither the duration nor the strength of an interaction establishes membership by itself. The question is whether the entity participates in the organisation of the process being examined. Identifying that process, its organisational level and the relevant timescale is therefore necessary before drawing its boundary.

5.4 Identity through Organisational Change

Persistence raises a further question: when components and relationships change, what makes the assembly the same entity?

Suppose an assembly has organisation O_1 at time t_1 and organisation O_2 at time t_2. Comparing those states alone may be insufficient. We also need to examine how the later state developed from the earlier one.

An organisation may progressively replace members and revise procedures while continuing its activities. Its later state develops through changes to its earlier organisation. A second organisation founded independently could have identical roles and procedures without being the same entity. Organisational similarity and continuity of identity are therefore different matters.

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Causal history connects successive states, but historical connection alone is insufficient. The products of complete disassembly also have a causal history connecting them to the former assembly. We must ask whether enough organisation was maintained through the intervening changes for that entity to persist.

This suggests that persistence can depend upon organisational continuity together with causal-historical continuity, rather than unchanged components or an invariant arrangement. Each state develops from preceding states while sufficient organisation continues.

There may be no sharp answer in every case. Gradual reorganisation can make the point of identity loss difficult to identify, and the relevant aspects of continuity may differ between machines, organisms and social organisations. The account provides questions through which identity can be investigated, rather than a universal threshold separating persistence from replacement.

5.5 Reliable Transfers and Self-Maintaining Organisation

A connected process can sometimes span separate entities through transfers across their shared environment. Material released by one entity may reach another and become its input. Where the connection depends upon chance encounters, however, the material may disperse, degrade or reach a different recipient before the required interaction occurs.

Configurations that retain participants or direct transfers can make the connected process more frequent, reliable or sustainable. Close proximity, compartments, retaining surfaces and directed flows provide different possibilities. Environmental flows can support the connections, so enclosure is not always necessary.

Retention must nevertheless remain compatible with continued operation. Required inputs must reach the participants, and products that inhibit further activity must be removed or kept below disruptive concentrations. A configuration can initially support a process and later prevent it if inhibitory products accumulate.

Autocatalytic networks provide a useful example. If catalysts and intermediate products disperse before participating in further reactions, connected activity may fail to continue. A suitable compartment or surface can retain them and improve opportunities for the required transfers.

The relationship can also become reciprocal. Processes supported by a containing configuration may produce or maintain that configuration. Hordijk and Steel (2015), for example, examine autocatalytic sets incorporating boundaries, including arrangements in which the network produces a boundary supporting its continued activity.

This suggests a route from occasional connected activity towards self-maintaining organisation: configuration supports the processes, and their activity helps maintain

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the configuration. Whether a particular case achieves this depends upon its actual interactions, continuing inputs and removal of disruptive products.

Where assembly maintains the relationships needed to produce or accept a system-level transfer, it can also sustain the emergent capability discussed in Section 4.4. The explanatory question is how the organisation preserves that capability between occasions of use.

Continuing transfers can also establish dependencies between assemblies. Individual exchanges may involve temporary assembly without maintaining a larger organisation. Where dependency gives rise to maintained relationships through which the participating entities operate as components of a more extensive assembly, those transfers can contribute to its formation and persistence.

5.6 Disassembly Can Remove or Release Capabilities

Disassembly changes the relationships through which capabilities are exercised. Its effects depend upon which roles and connections are lost.

An irrigation network may lose one branch while its remaining branches continue distributing water. Removing its only pump may instead stop distribution throughout the network, although much of the structure remains assembled. Loss of a component, loss of a capability and loss of the assembly's identity are therefore distinct possible consequences.

Disassembly need not always reduce activity. Removing a component can remove inhibition, open a restricted pathway or release an entity from constraints. Partial disassembly may consequently make a process more reliable, less reliable or no longer possible.

The same applies across organisational levels. Breakdown of a component can supply material for other processes or contribute to maintenance of a larger system. Conversely, preserving one component can consume resources required elsewhere. The significance of disassembly depends upon the organisation and process being considered.

5.7 Current Performance and Future Adaptability

A system can maintain its usual activity while losing capabilities that would matter under different conditions.

An organisation may reduce staff numbers without an immediate fall in routine outputs. Departing staff may nevertheless possess knowledge, skills and relationships needed to respond to unfamiliar circumstances. Their removal can narrow the organisation's available responses while leaving its established procedures operational.

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This explains how a pursuit of efficiency focused solely upon current activity can reduce adaptability. Resources or components that appear unused may embody latent capabilities. Removing them can preserve present performance while reducing the potential to respond to future demands.

Retaining every component is not automatically beneficial. Components can impose costs, inhibit activity or create vulnerabilities. The relevant question is which capabilities are retained or lost, what would activate them, and how important they may become under changing conditions.

Adaptability also requires more than possession of latent potential. Inputs must be able to reach the relevant components, and the organisation must allow those capabilities to operate together when required. A system may retain resources while losing the organisation needed to use them.

Current outputs therefore provide an incomplete basis for assessing continuing viability. We must also consider the physically retained capabilities and relationships through which the system could respond to change.

5.8 Connections between Systems Concepts

These explanations show how concepts often considered separately concern connected aspects of causal organisation.

Assembly establishes component relationships. Those relationships support processes and capabilities, while organised participation distinguishes the system from its environment. Maintenance allows the organisation to persist through transfers and replacement. Its causal history contributes to continuity of identity.

Changes to that organisation can extend capabilities, remove them or make previously inhibited activity possible. Inputs activate some retained capabilities, whose outputs may activate others and modify the system further. Such changes can support repair and adaptation or contribute to breakdown.

Causal Assembly Theory therefore provides more than a common vocabulary for describing systems. It identifies relationships through which their formation, boundaries, persistence, capabilities and change can be explained together. The next section considers how these explanations can guide investigation and further development.

6. Investigation, Further Development and Conclusions

6.1 Investigating Causal Organisation

Causal Assembly Theory provides a way to investigate how organisation is established, what maintains it and how it affects subsequent activity. An investigation begins by

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identifying the entity or process concerned, its organisational level and the period being examined. These choices establish which component relationships and transfers require explanation.

The investigation can then address four connected questions:

- How did the entities become organised as components?
- Which interactions and constraints maintain their participation?
- What capabilities does that organisation support, and which inputs bring them into operation?
- What changes would modify the organisation, remove capabilities or permit different activity?

Answering these questions requires identifying components, transfers and the physical mechanisms involved. Environmental circumstances and configurational or energetic constraints must also be examined where they enable, limit or prevent the relevant interactions.

Formation, maintenance and operation should be distinguished throughout. A process that originally established a relationship may have ended, while other interactions maintain it. Similarly, a capability may remain present even when the inputs needed to exercise it are absent.

6.2 Investigating Dependence upon Organisation

The contribution of organisation can be investigated by examining what happens when components are added, removed, rearranged or differently connected.

If a capability appears when a particular organisation is established and disappears or changes when that organisation is disrupted, this provides evidence that the organisation contributes to it. The explanation should trace which interactions, transfers or constraints changed and how those changes affected the result.

Such comparisons must also consider changes to the components themselves. An intervention may alter a component's properties as well as its relationships. A resulting change in activity should not automatically be attributed entirely to organisation.

Inputs and environmental conditions also matter. A process may stop because its organisation has been disrupted, because a required input has ceased, or because an inhibitor has become active. Distinguishing these possibilities helps identify what the proposed explanation actually accounts for.

The same approach applies to emergent capabilities. Investigation should identify the capability sustained by the assembly, the component contributions and the relationships connecting them. Observing an outcome once is insufficient to explain

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whether an assembled organisation maintains the capability to produce or accept the relevant transfer.

6.3 Investigating Latent Potential and Activation

Claims about latent potential require identification of its physical basis. The presence of a component does not establish every capability that might be attributed to it. Investigation must establish what the component and its organisation can do, what currently prevents that activity, and which inputs or changes would permit it.

It is useful to distinguish three situations: a capability is present but inactive; it remains physically embodied but access to it is constrained; or the components and relationships needed for it have been lost. These situations can produce similar observations under familiar conditions while permitting different responses when circumstances change.

Where activation is proposed to spread through a system, the explanation must connect successive stages. It should identify the initiating input, the capability activated, the resulting transfers and the further processes they affect. An observed sequence of changes does not by itself establish the proposed causal connections.

The effects should be assessed relative to the specified entity, organisational level and timescale. Activity that disrupts one component may maintain a larger assembly, while an immediate improvement in performance may reduce capabilities needed later.

6.4 Explanatory Reach and Supporting Evidence

The paper brings physical mechanisms and examples of organisation into a common causal account. The examples have different roles. Mechanical and chemical examples clarify formation and maintenance; protein rearrangement illustrates alternative capabilities; and fluid inclusions demonstrate how a retained entity can contribute to disruption.

These examples support the mechanisms they illustrate. Broader claims concern how such mechanisms combine across systems; for example, whether successive overlapping transfers maintain a configuration, how latent capabilities are inherited, or how activation propagates across organisational levels. These claims require investigation of the proposed relationships in the cases concerned.

The value of Causal Assembly Theory lies in helping to develop explanations that can be examined in this way. It directs attention from a descriptive label towards the components, interactions, transfers and constraints through which the phenomenon occurs. It also helps distinguish competing explanations: apparent capability loss may result from component removal, disrupted connections, missing inputs or continuing inhibition.

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Finding a similar pattern across domains provides a starting point for comparison. A stronger explanation identifies both the shared causal relationships and the particular mechanisms through which they operate in each domain.

6.5 Energy Landscapes and Further Physical Development

Energy landscapes provide a useful direction for developing the account. They can represent possible configurations, energy differences between them and barriers affecting transitions. This can help explain why some assemblies form readily, why others require an initiating input, and why particular arrangements persist (Carr et al., 2016).

Further work can examine which changes are physically possible, how readily they occur, and how these possibilities depend upon available energy, interactions and configurational constraints. Relevant cases include lower-energy bound states, metastable assemblies, transitions involving quantum tunnelling and organisation maintained through continuing inputs.

Energy landscapes should be connected with the interactions and transfers through which transitions occur. Identifying a lower-energy arrangement does not, by itself, explain whether the necessary pathway is available or how released energy is transferred. Likewise, identifying a barrier does not establish how long an assembly will persist under particular conditions.

Detailed physical case studies can make these relationships explicit by tracing formation, maintenance and disassembly within the same example. Such studies would also clarify how energetic and configurational constraints operate separately or together.

6.6 Further Systems Applications

The account provides a basis for investigating growth, maintenance, repair and regeneration as processes that add, replace or reorganise components. Further work should identify when these activities preserve an existing entity and when they establish a different one.

Adaptation can be examined through changes to the organisation supporting subsequent activity. This includes changes in latent potential, access to suitable inputs and coordination between capabilities. Resilience can likewise be investigated through the relationships that allow processes to continue, recover or reorganise following disruption.

Recurring and overlapping transfers warrant particular attention. Temporary connections may contribute to maintaining system configuration, while continuing transfers can establish dependencies between assemblies. Investigation should

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distinguish transient participation from the relationships sustaining a more persistent higher-level organisation.

Further work on emergence can examine how maintained organisation supports new capabilities to produce or accept transfers, and how these capabilities connect systems across organisational levels. Organisational nesting and emergent capability should remain distinct questions.

Applications to learning, memory and changes in knowledge require examination of the physical processes through which representations are established, retained, activated and modified. Their inclusion within a general causal account does not remove the need to identify the particular cognitive and representational mechanisms involved.

6.7 Conclusions

Causal Assembly Theory explains system formation, persistence and change through the interactions and transfers that establish, maintain, modify or end organised component participation. It connects these changes with physical mechanisms and the configurational and energetic constraints affecting them.

An assembly's organisation shapes what its components can do together. It can sustain capabilities between occasions of use, connect processes across organisational levels and persist while components enter, leave or are replaced. Inputs bring particular capabilities into operation, while activity can alter the organisation supporting future processes.

This connects familiar systems concepts through a common causal account. Boundaries concern organised participation; persistence concerns continuity through change; emergence concerns capabilities maintained by assembled organisation; and adaptation or breakdown can involve changes to the components and relationships supporting those capabilities.

The contribution to General Systems Theory is therefore both explanatory and investigative. It relates systems concepts to mechanisms described by contemporary physics and provides questions through which their operation, interrelationships and wider application can be examined.

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Definitions

D2.8 – Collection
A plurality of entities considered together on the basis of a shared feature, circumstance, or condition of selection.

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D2.13 – Configuration
The overall spatial, temporal, or spatio-temporal arrangement of a plurality of entities.

D7.1 – Causal Assembly
Causal assembly is a causal process through which previously separate entities become organised as components of a more extensive entity.

D5.6 – Process
An organised causal transformation in which inputs of matter, energy, or information are acted upon to produce outputs of matter, energy, or information.

D5.8 – Assembly (Updated)
An assembly is an organised entity resulting from, or subsequently modified through, causal assembly, whose organisation includes two or more entities as components.

D5.9 – Pre-Systemic Assembly (Updated)
A pre-systemic assembly is an organised assembly that does not sustain an emergent causal capability.

D5.10 – System (Updated)
A system is an organised assembly whose maintained organisation supports a capability to produce or accept transfers that its components do not possess acting separately.

D5.17 – Component (Updated)
An entity participating in the organisation of a more extensive entity is a component of that entity. Such participation may include physical retention and constraint and need not involve a contribution to the interactions constituting its focal organisation or function.

D7.2 – Disassembly
Disassembly is a causal process through which the organisation of an assembly is sufficiently changed for one or more entities to cease participating as components of that assembly.

D7.3 – Partial Disassembly
Partial disassembly is disassembly in which one or more components cease participating in an assembly while sufficient organisational continuity remains for the assembly itself to persist.

D7.4 – Complete Disassembly
Complete disassembly is disassembly in which sufficient organisation is lost for the previous assembly to cease to persist as that entity.

D7.5 – Whole-Entity Transfer
Whole-entity transfer is a causal transfer in which the entire source entity becomes

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incorporated with the recipient into a more extensive assembly. The transferred entity need not lose its identity or internal organisation, and incorporation need not involve spatial relocation.

D7.6 – Whole-Component Transfer
Whole-component transfer is a causal transfer involving an entire component of a source assembly. Its participation in the source ends, and it may remain in the environment or become incorporated into a recipient assembly. Where incorporation occurs, it may begin after, as or before participation in the source ends.

D7.7 – Causal Coupling
Causal coupling exists where the state or behaviour of one component causally constrains, enables or influences the possible states or behaviour of another.

D7.8 – Organisational Continuity
Organisational continuity is the continuity between successive organisational states of an entity despite possible changes in its components, configuration, relationships, constraints or component roles. Continuity can accommodate organisational change without requiring an unchanged overall pattern.

D7.9 – Causal-Historical Continuity
Causal-historical continuity is the continuity between successive states of an entity arising from the causal development of each organisational state from preceding organisational states.

D7.10 – System-Level Causal Capability
A system-level causal capability is a capability to produce or accept transfers that depends upon an assembly's maintained organisation and is not possessed by its components acting separately.

D7.11 – Causal Emergence
Causal emergence occurs where an assembled entity possesses a capability to produce or accept transfers that depends upon its maintained organisation and is not possessed by its components acting separately.

D7.12 – Prior Disassembly
Prior disassembly is a temporal relationship in transfer between assemblies in which the transferred material ceases participating in the source before its incorporation into the recipient begins.

D7.13 – Concurrent Disassembly and Assembly
Concurrent disassembly and assembly is a temporal relationship in transfer between assemblies in which incorporation into the recipient begins as participation in the source ends.

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D7.14 – Subsequent Disassembly
Subsequent disassembly is a temporal relationship in transfer between assemblies in which incorporation into the recipient begins before participation in the source ends. The resulting period of overlapping participation may be brief or extended.

D7.15 – Configuration-Preserving Transfer
Configuration-preserving transfer is transfer during which a transferred assembly retains its relevant internal configuration despite changes in its external incorporation. The configuration and organisational level being considered must be specified.

D7.16 – Latent Causal Potential
Latent causal potential comprises physically embodied causal capabilities that are not currently realised because the relevant interacting entities, inputs or enabling conditions are absent, or because constraints inhibit their operation.

D7.17 – Alternative Configurational Potential
Alternative configurational potential is the physically embodied capacity of an assembly's existing components to assume alternative configurations through which different causal interactions become possible.

D7.18 – Configurational Entrainment
Configurational entrainment is causal incorporation and retention through a developing or changing configuration, without the retained entity participating in the constitutive interactions responsible for the specified focal organisation.

D7.19 – Configurationally Entrained Component
A Configurationally Entrained Component, or CEC, is an entity incorporated and retained through configurational entrainment. Its status is relative to a specified focal organisation and level of assembly.

D7.20 – Entrained Latent Causal Potential
Entrained latent causal potential comprises the unrealised causal capabilities of configurationally entrained components within a containing assembly.

Propositions

P7.1 – Assembly is a causally produced change in organisation.
Previously separate entities become components of a more extensive entity through causal processes; assembly does not require a distinct or additional form of causality.

P7.2 – Assembly is distinguished from collection and configuration by organisational participation.
Entities may be considered together or occupy a spatio-temporal configuration without constituting an assembly. Assembly occurs only where they become organised as components of a more extensive entity.

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P7.3 – Configuration can alter causal possibilities without constituting assembly.
The spatial and temporal arrangement of entities may enable, inhibit or constrain interactions and processes without the entities thereby becoming components of an assembly.

P7.4 – Assembly is independent of any single assembly mechanism.
Assembly can arise through different physical interactions and transfers under suitable conditions, including processes directed by agents. Whole-entity transfer, as defined here, incorporates an entire source entity into an assembly. Component transfers and energy transfers can also establish or modify organised component participation; assembly is not confined to whole-entity transfer.

P7.5 – Formation and persistence are distinct causal questions.
The causal processes that produce an assembly need not be the same as the circumstances, conditions, constraints or interactions through which the resulting organisation subsequently persists.

P7.6 – Quantum Binding and Persistence Proposition
At quantum scales, physical interactions and energy transfers can establish bound assemblies. Once formed, such an assembly need not receive continuing net energy input to remain bound. Its persistence depends upon the resulting bound state and the conditions permitting or preventing separation or breakdown.

P7.7 – Energetic Pathways and Persistence Proposition.
Formation and disassembly depend upon available energy and the physical interactions through which transitions can occur. An assembly may persist in a bound state or in a local energy minimum separated from lower-energy arrangements by barriers. Formation or disassembly may require an initiating energy input, release energy, or involve both. Quantum tunnelling can permit some transitions through barriers.

P7.8 – Persistent organisation provides causal potential.
Once established, an assembly's organisation, together with its components' properties, can enable or constrain subsequent causal processes. Appropriate interacting entities, input transfers and conditions can realise this potential. The processes currently realised need not exhaust the assembly's physically embodied capabilities, and changed circumstances may permit previously latent capabilities to operate.

P7.9 – Assembly can alter system-level causal capability by altering organisation.
Assembly may establish configurations, relationships and constraints that enable, inhibit or coordinate the existing properties and capabilities of components in ways unavailable while those entities were independently organised.

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P7.10 – An assembly can be both a causal effect and a subsequent causal participant.
An assembly is produced by preceding causal processes but, once formed, may act as a source or recipient within subsequent causal processes.

P7.11 – Assembly and disassembly may occur throughout the persistence of an entity.
Assembly is not necessarily confined to initial system formation. Assemblies may progressively acquire, lose, replace or temporarily incorporate components while continuing to operate and persist.

P7.12 – Component membership is organisational rather than merely spatial or classificatory.
An entity is a component insofar as it participates in the organisation constituting an assembly. Crossing a spatial boundary or occupying the same region does not by itself establish component membership.

P7.13 – Changing component membership need not change the process boundary.
Entities may enter and leave a process while its organisation and spatial extent remain broadly stable. Supplying inputs, receiving outputs or otherwise influencing the process does not by itself make an external entity a component. Membership depends upon participation in the organisation of the specified process.

P7.14 – Disassembly is the organisational complement of assembly.
Disassembly occurs when causal change sufficiently alters an existing organisation for one or more entities to cease participating as components of the previous assembly. It need not require destruction of the components or their immediate spatial separation.

P7.15 – Disassembly can alter causal capability independently of component survival.
Partial disassembly may remove or modify system-level causal capabilities while leaving others intact, while complete disassembly removes capabilities dependent upon the organisation of the former assembly even though its former components may persist.

P7.16 – Component loss can reduce latent causal potential without disrupting current processes.
Removal of components may eliminate capabilities that are not required for an assembly's current operation but could become relevant under different inputs or conditions. Current processes may therefore continue even though the range of possible responses to changed circumstances has narrowed.

P7.17 – Transfer can connect disassembly and assembly through different temporal relationships.

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Where material is released from a source assembly and incorporated into a recipient assembly, its participation in the source may end before, as or after incorporation into the recipient begins. These organisational changes may therefore be sequential, concurrent or overlapping. The transferred material need not constitute a whole component.

P7.18 – Changes in external membership need not immediately disrupt internal organisation.
An assembly may leave a source and become incorporated into a recipient while retaining its identity and internal organisation. Such preservation is possible under prior, concurrent or overlapping changes in participation, but depends upon the conditions of transfer. Subsequent processing within the recipient may transform or disassemble the transferred assembly.

P7.19 – Assembly and disassembly can occur as operations within larger causal networks.
Transfers, transformations, assembly and disassembly may occur in linear, branching, converging, cyclic and feedback arrangements, with assemblies produced at one stage becoming causal participants at subsequent stages.

P7.20 – Causal processes can modify the organisation through which subsequent causality occurs.
Assembly, disassembly and reassembly may construct, modify or remove components, relationships and constraints and thereby alter the causal network through which later processes operate.

P7.21 – Assembly can operate recursively.
An assembly may itself become organised as a component of a more extensive assembly while retaining its own internal organisation. An entity may consequently be an assembly relative to its components and simultaneously a component relative to a more extensive entity.

P7.22 – Existing assemblies can alter the causal conditions for further assembly.
Through their system-level causal activities, existing assemblies may produce, concentrate, direct or transport matter, energy or information required for assembly elsewhere and can therefore alter circumstances, conditions or constraints affecting subsequent assembly.

P7.23 – Alternative configurations can enable different causal interactions.
An assembly may possess physically accessible alternative configurations of its existing components. Changes between these configurations can alter the interactions and processes available to it without requiring additional entrained components.

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P7.24 – Configurational entrainment can introduce additional causal capabilities.
Entities retained within an assembly without participating in the constitutive interactions responsible for its focal organisation nevertheless possess physical properties and causal capabilities. Some of these capabilities may remain latent under prevailing circumstances.

P7.25 – Recursive incorporation can carry entrained components across organisational levels.
Where an assembly containing CECs becomes incorporated into a more extensive assembly, its retained CECs become nested within that assembly unless removed or transformed. Their subsequent causal possibilities depend upon the circumstances and constraints established at the higher level.

P7.26 – Organisational effects are relative to a specified entity, level and timescale.
Whether a process supports or undermines organisation must be assessed relative to a specified entity, organisational level and timescale. Disassembly or disruption at one level may contribute to persistence at another, while support for one component may undermine the assembly containing it.

P7.27 – Organisational–Historical Persistence Proposition (Hypothesis)
The persistence of an assembly may depend upon sufficient organisational continuity together with causal-historical continuity between successive organisational states, rather than upon unchanged component membership or invariant organisation.

P7.28 – Continuity through Concurrent or Overlapping Incorporation Proposition (Hypothesis)
Where continued incorporation supplies support or causal coupling necessary to maintain a transferred component's organisation, incorporation into a recipient before or as release from the source occurs may help preserve that organisation. This contribution depends upon compatible relationships and constraints and is not guaranteed by temporal overlap alone.

P7.29 – Configurational Support for Reliable Transfers Proposition (Hypothesis)
Where a process depends upon transfers between participating entities, configurations that retain the required entities or direct transfers between them may make the process more frequent, reliable or sustainable. This depends upon continued access to necessary inputs and the avoidance of disruptive accumulation of inhibitory products.

P7.30 – Ontological Hierarchy Proposition (Hypothesis)
Recursive assembly may establish levels of physical organisation where assemblies become components of more extensive assemblies. Such nesting need not establish a new emergent capability at every stage. Where maintained organisation supports a capability unavailable to the components acting separately, a further distinction in emergent capability can be identified.

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P7.31 – Increasing Complexity Proposition (Hypothesis)
Existing organisation may contribute to increasing organisational complexity by creating causal conditions that enable further assembly, although assembly does not imply that complexity must continually or monotonically increase.

P7.32 – Dependency–Integration Proposition (Hypothesis)
Where dependency gives rise to maintained organisational relationships between entities, those entities may become components of a persistent, more extensive assembly. Individual exchanges may involve transient assembly without establishing that persistent organisation.

P7.33 – Causal Emergence Proposition (Hypothesis)
An assembly may possess an emergent causal capability where its maintained organisation enables it to produce or accept transfers that its components cannot produce or accept acting separately. This capability can persist while inactive, provided the organisation sustaining it is maintained.

P7.34 – Organisational Dependence Proposition (Hypothesis)
Where a capability appears following assembly and is lost or modified when the relevant organisation is disrupted, while component capabilities remain substantially unchanged, this provides evidence that the organisation contributes to that capability.

P7.35 – Growth, Maintenance, Repair and Regeneration Proposition (Hypothesis)
Growth, maintenance, repair and regeneration may be understood partly as continuing processes of assembly, disassembly and reassembly through which components are added, replaced or reorganised while sufficient organisational and causal-historical continuity is maintained.

P7.36 – Adaptation Proposition (Hypothesis)
Adaptation may occur where processes acting through an existing organisation modify that organisation through assembly, disassembly or reassembly, thereby changing the causal possibilities available to subsequent processes.

P7.37 – Epistemic Assembly Proposition (Hypothesis)
Learning, memory, theory formation and theory revision may involve physical causal processes through which the organisation supporting epistemic representations is assembled, maintained, activated, modified or partially disassembled.

P7.38 – Causal Algorithm Proposition (Hypothesis)
The causal organisation of a process may in some cases be representable as a temporally organised network of causal relationships expressible symbolically as a causal algorithm.

P7.39 – Living Organisation Proposition (Hypothesis)
Assembly, disassembly and reassembly may provide some of the causal mechanisms

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through which living organisation is produced, maintained, repaired and modified, while sufficiently extensive disruption of such organisation may contribute to the loss of the living entity.

P7.40 – Identity-Loss and Death Proposition (Hypothesis)
Sufficiently extensive disassembly or organisational disruption may cause an assembly to cease to exist as the same organised entity even where much of its constituent matter persists.

P7.41 – Propagation of Latent Capability Activation Proposition (Hypothesis)
Inputs from the environment or transfers within a system may activate latent causal capabilities. Outputs from the resulting processes may become inputs to other components and activate further capabilities. Where the necessary connections and enabling conditions exist, this sequence may propagate across one or more organisational levels, supporting, modifying or disrupting the system's organisation.

P7.42 – Configurational Continuity Through Subsequent Disassembly (Hypothesis)
Where transfers involving subsequent disassembly maintain physical coupling between components, successive temporary connections may sustain a system's configurational structure despite continuing transfers and changes in participation. This requires sufficient overlap to preserve continuity of the physical interactions and constraints maintaining that configuration.

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