Human agency over mind and matter: An ecosystem framework for describing the objective reality of material-, neural activity- and story-based social entities.

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The human mind can model and causally change entities as diverse as atoms, rivers, biological species, and societies. Assuming the mind arises from neural activity, how can such activity represent the behavior of objects, sometimes accurately imagining interactions not previously encountered? How can the human mind and body form a self, acting as a cohesive system with agency over mental and physical processes? To make self and mind accessible to scientific analysis, I introduce a physics-based framework to describe any entity via an ecosystem of dimensionally constrained interactions. All entities can be modeled by ecosystems that evolve their subsystem components towards a stable state, They respond with characteristic forces to internal or external disturbances and become identifiable objects by creating non-random perturbations of existing flow environments. Philosophically, the ecosystem framework has common elements with Object-Oriented-Ontology as well as Transcendental Idealism but is here rationalized into a scientific approach, potentially termed Objective Realism. Physical objects, mental concepts and story-based social entities are considered equally real. Their existence is based on interactive geometric and probabilistic principles, subject to coherent scientific interrogation. The framework is applicable to macro- as well as microscopic systems and elucidates means to encode processes into templates.

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Introduction

One of the most fascinating problems in neuroscience is to understand how the human brain with its nearly 90 billion neurons and on the order of 100 trillion synapses can create coherent mental representations of the world around us (Kandel 2018). It might be even more fascinating to contemplate how such representations not only model occurrences outside the physical body but allow human beings to assert purposeful agency over those occurrences in the real world (Haggard 2017). Many neuroscientists have proposed reductionist approaches to study mind and self in the context of behaving organisms (James 1890, Crick, Dreyfus et al. 1983, Baars 2005, Damasio 2010, Koch 2012, Kandel 2018). Aspects of mental perception by the biological brain have been described by bottom-up as well as top-down processes (Dehaene and Naccache 2001, Baars 2005, Hunt, Malalasekera et al. 2018). Nonetheless, many believe that understanding mind and self at a systems level will require new mathematics or be out of reach of a scientific approach altogether (Edelman and Tononi 2000, Chalmers, Manley et al. 2009, Varela, Thompson et al. 2016). I argue here that mind processes, giving rise to percepts, feelings, thoughts and memories, are built on the same geometric, probabilistic and interactive principles as physical objects. The terms “object”, “system” and “entity” are portrayed the way that Object-Oriented-Ontology (OOO) describes physical and sensual objects (Harman 2018). On the other hand, objects arise and are sustained by flows and processes within and between pre-existing ecosystem environments, making the framework introduced here more alike to process viewpoints, such as the interactivism framework of Mark Bickhard (Bickhard 2009). Possibly, the framework is unique in that it argues that all objects, whether physical, mental, or social, arises from common principles and can be uniquely ontologically characterized based on their interactivity within and between physical and mental ecosystem environments. Physical and mental environments are not isolated. Mental objects can form representations in the physical realm via art and technology, and physical objects can form mental representations via concepts and ideas. Both are part of an overlying reality which I call the story-verse. In it, real story-based objects, including conscious human beings, can form, evolve, and interact by creating representations of their processes in the physical and mental realms.

To allow a science-based description all objects and their environments, I will introduce a framework that applies a simple principle, *dimensionally constrained self-reinforcement*, to describe any kind of entity as an ecosystem of evolving, self-reinforcing, interaction patterns. The framework should not entail novel

mathematics, nor require changing any natural laws of the physical world. Rather, it offers a shift in modelling physical entities that allows to concurrently describe properties of mental (Kant 1787) and intersubjective social entities (Harari 2015). Reality is based on physical causality, akin to a type of naïve realism suggested by Lee Smolin (Smolin and Bradonjic 2019), but here all types of objects are considered real rather than dependent on the reality of other objects. Therefore, I would like to suggest **Objective Realism** as a descriptive term for this framework.

Shifts in perspective

To describe physical, mental, and social phenomena in a common scientific language, the framework requires a shift in perspective to define objects by their internal and external interactivity, rather than solely by their constituents. The principles required for this shift have their foundations in ecology, but also rely on information theory and physics:

- The first conceptual pivot is that entities, even protons and atoms, are not viewed as made of solid things but as propagating systems, self-reinforcing interaction patterns arising under the constraints of a flow environment (Rovelli, Carnell et al. 2017). In such an environment, objects propagate along a flow axis and maintain their identity by constraining dissipation. Types of objects are categorized according to nature of their flow environment and dimensionality of interactivity. Here, we describe entities in three different ecosystem environments: **a)** material entities evolve in time and are sustained by **spatially** constrained self-reinforcing interactions: kinetic (point to point), gradients (surfaces), informational (spatial conformations) and by through their history (spatiotemporal); **b)** neural activity-based entities evolve along a spatial flow environments (dendrites, axons and synapses) but constrain dissipation via **temporally** self-reinforcing interactions: coincidences, durations, frequencies and narrations; **c)** story-based social entities form via self-reinforcing interactions within and between organisms with a nervous system and take advantage of **spatial and temporal** constraints, dimensionally expanding their flow environment.

- The second conceptual pivot is that any object creates an ecosystem within its internal (subjective) flow environment, constraining formation and evolution of nested subsystems. Every object is also part of an external (objective) environment through which it can interact with other objects through flow perturbations. New objects manifest when recurring perturbations create a self-reinforcing interaction pattern. Once formed, objects evolve by exerting environmental forces on participating subsystems, forcing them to adapt

until a stable state is reached (Ulanowicz 1995). Beautiful examples for formation and development of objects as flow systems are described by Robert Ulanowicz in his books (Ulanowicz 1986, Ulanowicz 1997, Ulanowicz 2009) and large body of primary research in ecology (Ulanowicz 1995, Ulanowicz 2003).

- Lastly, because objects are built from flow interactions and not from subsystems, subsystems participating in self-reinforcing interactions do not need to be exclusive, nor even essential for a single object. Rather, an object and its subsystems will be in a mutually co-dependent relationship, in which causal flows move top-down and bottom-up. Top-down flows create an internal environment in which subsystems compete for resources and are subject to natural selection (Kauffman 1995, Ulanowicz 1997). Bottom-up flows constrain the ability of an object to adapt to its external environment. The combination of top-down and bottom-up flows creates an objective identity, that can causally interact with environmental systems.

These shifts in perspective have important consequences for how we view self and agency in any kind of object, whether based on physical interactions, neural activity or the exchange of stories. Top-down flows pattern the internal environment and thus result in natural agency over subsystems. Atoms have agency over locations of protons and electrons. Hurricanes have agency over gradients of water and air molecules. Genes have agency over replication of DNA, RNA and protein sequences. Organisms have agency over adaptive behaviors. Organisms with a nervous system expand the dimensionality of their flow environment and can model effects of flow perturbations via mental representations, gaining agency over external systems by purposefully perturbing their environment. Agency is a direct result of system generated flows that can be described, perturbed and therefore studied. The aim is to lay the groundwork for a mathematical description of the causal relationship between the subjective self and the objective identity of any kind of object. Thus, the self of an object (noumena) can be studied by causal responses to perturbation of its environment. Conversely, its environmental identity can be studied by observing interactive responses (phenomena) to perturbing its underlying self-reinforcing interaction pattern. Such data combined with the framework principles should result in computational models testable against well-established physics descriptions. Concepts can then be extended to objects built on neural activity (mind), and story-based objects built on interactions of, thus agency over, matter and mind.

Goals and Definitions

The goal of the framework is as simple as its potential application might seem preposterous: Create a verifiable scientific description of any physical and mental phenomenon, including formation, evolution and causal effects on other phenomena in its environment. Causality is the key because any causal effect has an origin that can be observed, modelled and perturbed. Mental processes are mostly excluded from such description because they appear subjective to the individuum and cannot be directly observed. On the other hand, nobody should argue that mental processes have no causal effects. Ideologies, technologies, rational structures are resulting forces of such processes, often originating from a single individual. Descriptions of the world as interconnected networks of systems were suggested by other authors (Capra and Luisi 2014, Noble 2017) but defy reductionist approaches by sheer complexity. Here, each object is treated as single, even selfish, entity that can be described, studied and perturbed. A full model will be mathematically complex. Here I will focus on the concepts required to build computational models and hypothesize how to apply them. Because of the shift in perspective and supposed validity across my diverse fields, it will be somewhat challenging to find a common language. Box 1 contains a glossary for explaining the use of common terms in the context of this framework.

BOX 1: Terms and Definitions

Flow: dimensionally constrained propagation of a recurring interaction pattern.

Flow Surface: a propensity distribution for a pre-patterned, dimensionally constrained interactive flow environment.

Force: a propensity distribution within a flow surface that increases the likelihood for interaction patterns to propagate directionally rather than equiprobable.

Constraint: probabilistic resistance that dimensionally limits the propagation of a recurring interaction pattern along a force gradient.

Causal effect: non-random effect of a *force* or *flow*.

Evolution: the causally constrained propagation of a recurring interaction pattern across spatial and/or temporal dimensions.

System/Entity/Object: an evolving self-reinforcing interaction pattern in the context of pre-existing environmental flows.

Stable System: system whose objective flows do not causally change environmental flow perturbations over evolutionary recurrences.

Process: a propensity distribution for recurring system evolutions from formation to dissolution.

Process Boundary: spatiotemporal probability limits for the formation and evolution of a self-reinforcing interaction pattern in the context of a pre-existing flow environment.

Process Template: pre-patterned environment on a flow surface, shaped by previous system evolutions and providing propensities for the re-occurrence of similar system evolutions as part of a higher order system.

The language for the definitions might initially sound unfamiliar because objects are not made of solid things but of recurring flow perturbations, themselves the result of other objects. If the framework is

validated and found useful, in the spirit of poetic naturalism (Carroll 2016), these definitions should be coherent with other uses of the terms. Most importantly they should result in a common language for fields as diverse as physics, biology, ecology, psychology, and sociology. In the following sections, I will try to unravel each term for physical entities before applying them to the mind and higher-order social systems. The goal is not to answer “the meaning of life, the universe, and everything” (Adams 1980) but to broaden the scientific scaffold for asking questions so far considered unapproachable. If validated, the framework potentially expands scientific interrogation in three areas: 1) It is based on a simple principle, *dimensionally constrained self-reinforcement*, that can be applied to macroscopic as well as microscopic entities. 2) It elucidates the means for entities to encode processes into representative templates, e.g., the sequence of DNA molecules. 3) It allows for mental and physical objects to evolve in their own ecosystems and simultaneously act as templates for each other’s processes.

Flow surface environments for systems to form and evolve

The following four sections might be the most challenging for many readers. Not necessarily because of complexity but rather because they recast our view of physical objects. However, the patient reader will be rewarded with a description of physical reality that is equally valid for mental and social phenomena. Moreover, the viewpoint suggested here may resolve incompatibility problems between current models on various physical scales. If successfully validated, attributes like particle/wave duality, quantization of space, relativity of spacetime and higher dimensional constraints, follow directly from the first principles of the framework, rather than requiring further explanations. To achieve such a description, the framework views all objects as embedded in multi-dimensional flow surfaces that constrain how they can evolve and interact. This is not dissimilar to current models of matter evolution in four-dimensional spacetime (Einstein 1916, Witten 1995, Rovelli 2004). We will expand dimensionality even beyond the four dimensions of conventional spacetime, but it is difficult to visualize higher dimensional surfaces. Thus, we start with an example of a more intuitive flow surface: the surface of a river. River surface wave evolution allows us to establish boundaries, flows and constraints applicable to all types of flow surfaces. Wave evolution on a river surface has the interesting feature that propagation evolves primarily spatially (downstream) rather than temporally. This introduces another difficult but necessary challenge for the reader: Whenever talking about processes in general, I will refer to space and time in relationship to conventional spacetime. However, when talking about

coordinates for a specific object or process, I will use temporal terms for propagation along the *flow* axis and “space” or “spatially” for dissipative constraints. The relativity of spatial and temporal axes will be especially important when describing neural activity-based objects. The river surface provides an attractive first example. It is not meant as a metaphor but as a real-world example for modelling flow systems; one that we will return to again and again when discussing higher-order environments. If the framework is understood and verified at the level of a river surface, computationally modelling other entities, including molecules, genomes, mental concepts, artistic interpretations and human social constructs, should just be a matter of varying complexity.

From a high-level ecosystem view, a river is part of the global water cycle governed by the earth’s biosphere . A river surface is constrained by the shape of the bed and flows of air and water molecules. It forms a two-dimensional bendable flow surface, providing a dynamic environment for evolving wave systems. The surface is a purely interactive environment, created by molecules stochastically popping in and out, allowing for constrained propagation. To draw a coordinate system for the dissipation of events, e.g., spontaneous formation of a ripple, or a stone thrown into the water, we describe event propagation relative to river surface coordinates (Fig. 1A). We assume the surface itself does not causally change over time but assign each surface coordinate propensities allowing for stochastic changes of environmental conditions. Flow is determined by surface properties and gravity. This way, we can observe events dissipating along their downstream evolution, while allowing for probabilistic surface variations at each flow through. We arrive at a coordinate system that distinguishes *flow surface* coordinates from the direction of a *dissipative force*, in this case a gravity gradient towards the earth center (Fig. 1B).

Figure 1. A. Coordinates for the flow surface of river wave systems. The orthogonal flow and space dimensions describe the flowspace of the river surface. The dissipative force, points along the gravity gradient, orthogonal to the default flowspace. **B.** At any point of the river surface, the orthogonal flow and space dimensions rotate with the surface according to environmental river constraints and/or system induced bending of the river surface. **C.** General model for a process imbedded in a flow surface. Process boundaries are propensities for a system to form and evolve at defined locations of the flowspace. See Box 2 for definitions of the flow related (temporal) terms: *chronous*, *diachronous* and *kairos*.

On a lake surface, orthogonal to the gravity gradient, events dissipate equally in all directions. On a river surface, downstream becomes distinct from its orthogonal axis (toward the riverbank), subjecting any surface object to a force making downstream propagation much more likely than upstream propagation. Relative to the default coordinate system, the vector of the flow axis, and thus direction of propagation, rotates at each point of the surface, with the downstream force depending on exposure to gravity. The river surface gives thus rise to a flow environment in which surface objects can form and evolve. There will be locations where the combination of forces gives rise to high probabilities of recurring ripples via downstream propagating oscillations (Moglen 2015). Without major changes to water flow, shape of riverbed or air flow, ripples forming at these locations will follow similar but likely not identical, progression towards points of dissipation, collapsing, or decohering flow propensities during *system evolutions*.

For physical objects, the flow surface is bendable spacetime, as described by Einstein (Einstein 1916). Propagation, whether the evolution of organisms or a planet evolving around the sun, is generally described as a function of time. However, the term “*time*” can be rather obscure and can convey many different meanings (Carroll 2010, Buonomano 2017, Rovelli, Segre et al. 2018). To describe formation and evolution of any object in any flow environment, we must differentiate several environmental characteristics that could be referred to as temporal. For physical objects, these will describe the properties of spacetime:

- **time** as the **likelihood** for coincidental occurrences (kairos), is determined by the environment of natural laws setting the probabilities for interactions to become self-reinforcing, resulting in a positive feedback loop and emergence of a representable identity, such as the tick of a clock, or the fertilization of an organism.
- **time** as the **relative frequency** of recurring occurrences (chronous), is how we measure the passing of time. We compare the known frequency of a clock ticking, or a crystal pulsing, with the representable progress of a process, like the aging of an organism. This environmental characteristic determines flow forces within the ecosystem, i.e., how fast time passes.
- **time** as the **sequence** of evolving occurrences (diachronous), determines the order of state changes within a directional process. This characteristic can be represented by the sedimentation history such changes leave behind.

For physical objects in the spacetime ecosystem, all these characteristics are linked by the natural laws governing elementary particle interactions, with the speed of light in vacuum acting as constant for determining a present from past and future (Carroll 2019). However, when generalizing aspects of time across different types of ecosystems, we must treat them as independent variables. Box 2 suggests a naming convention for characteristics of flow progression and environmental spaces governing them.

Box 2: Flow characteristics of objects propagating in a flow surface

kairos: propensity for flows to become self-reinforcing at a given flow surface coordinate – determines likelihood of recurrences.

chronous: relative frequency of recurring (resonating) interactions – determines flow force.

diachronous: relative sequence of recurring (evolving) interactions – determines directions of flow.

chronous space: External environment that determines flow force and bending characteristics of a flow surface.

diachronous space: Prepatterned flow surface environment that determines probabilities for interactions along the flow direction.

Applying flow characteristics to a general evolutionary process (Fig. 1C), we define the axis along which we measure sequential flow progression as *diachronous axis*, while other axes within the flow surface but orthogonal to the flow are considered *space axes*. Together they create a *diachronous space* within **process boundaries**. For physical objects, the diachronous space is the spacetime environment of the universe, with the diachronous axis corresponding to the direction of time.

The direction of a *dissipative force* acting onto but distinct from the flow surface is called a *chronous axis*. Exposure of a flow surface towards this axis increases relative flow progression, i.e., frequency of recurring interactions relative to surface areas with less exposure. Probabilistic boundaries of recurring ripple evolutions form a *process boundary* (Fig. 1C). The *evolutionary endpoint* is defined as the point where probable interaction patterns of a process no longer contribute to their own recurrence. The patterned (hyper)space into which the surface bends, is called a *chronous space*. This space dimensionally surrounds and constrains the flow surface, establishing the laws for bending probabilities. For wave systems propagating along a river surface, *chronous space* is the conventional matter space into which the river surface bends. From the viewpoint of an evolving ripple, which forms from wave interactions on the surface rather than the underlying matter, this space would be as exotic as the ten-dimensional hyperspace bulk to matter-based physics, which constrains spacetime according to string theory (Witten 1995). For the description of physical objects, the ecosystem framework would require a force that acts onto four-

dimensional spacetime to constrain flow and bending properties. The Higgs Field (Englert 1964) could be a candidate for conveying such a force by bending spacetime through interactions that give mass to particles.

Evolution via self-reinforcement of flows and constraints

Evolution via self-reinforcement of preexisting flows is not a new concept. Maturana and Varela formulated the concept of *autopoiesis* in 1974, with systems establishing a dynamic identity that can interact with their environment by creating an objective boundary around themselves (Varela 1974). Kauffman later showed that even small peptide chains can form and evolve self-replicating systems via autocatalysis and natural selection when given sufficient interactive complexity (Kauffman 1986). Ulanowicz took a parallel path by using matter-flow exchanges to characterize the development of ecological ecosystems (Ulanowicz 1972). He showed that mutual matter flow between species results in causal development of ecosystems spanning a trajectory with distinct phases, from formation, growth, development, maturity to stability, followed by senescence to eventual death or renewal (Ulanowicz 1997). During this developmental trajectory, the mutual information (Ascendency) of the ecosystem initially tends to increase towards the development potential until it achieves a state of stability, in which overhead (comparable to random noise) and mutual information reach a balance that allows sufficient flexibility to adapt to environmental changes, i.e. a state of maximal fitness (Ulanowicz 2009). Ulanowicz's approach is especially applicable to the ecosystem framework because **a)** if any object can be described as an ecosystem, then his research on ecological ecosystems becomes relevant to all objects, **b)** his analytical approach to ecosystem evolution based on information theory, Ascendency being a measure of self-reinforcement, should be translatable to developmental trajectories of any entity, including atoms and societies. Ulanowicz is not alone in using flow exchanges to show directionality of process development. Bejan argued for a new constructal law of thermodynamics that governs evolution by minimizing entropy dissipation (Bejan 2005) and is applicable to all evolutionary processes (Bejan 2016). Juarrero (Juarrero 1999), and subsequently Deacon (Deacon 2012) focused on the constraints created by autocatalysis in the formation of living organisms. Arthur recognized the positive feedback loop resulting from self-reinforcement in processes, first in economic systems (Arthur 1988), and then also applied them to the evolution of technologies (Arthur 2009), and Kurzweil formulated positive feedback of processes into the "law of accelerating returns" (Kurzweil 1990). All these descriptions share a common principle: any entity in a flow environment, such as matter in the conventional spacetime surface,

forms and evolves via self-reinforcement of environmental flows. Self-reinforcement results in a centripetal force that directs evolution of an object towards its developmental potential (Ulanowicz 1997). Internally, it creates a dynamic environment that applies selection pressure on objects participating in its self-reinforcing interaction pattern, forcing them to adapt to environmental changes. In other words, **all objects are evolving ecosystems made by and directing environmental forces as a result of positive feedback.**

Fundamental interactions as perturbation flows in physical spacetime

Above, I introduced the concept of objective identities arising from self-reinforcing environmental flows. Prior to applying these concepts to the formation of particle-based objects in the spacetime environment, I would like to briefly return to how flow perturbations propagate on a river surface. A two-dimensional surface allows two types of flow forces: **one-dimensionally constrained flow vectors (i1)**, for example describing surface perturbations resulting from a stone throw; **two-dimensional flow vectors (i2)**, describing the rotational perturbation of a vortex. Any individual object, such as a vortex, expresses itself via the following recurring perturbations: one-dimensional vectors resulting in lateral wave propagation (i1) or two-dimensional vectors resulting in rotational surface bending (i2). There are important characteristics to such objective flows that can be visualized by a vortex: one-dimensionally constrained flow forces originating from an object always act towards its outside (centrifugal), increasing dissipation or spatially moving subsystems. Two-dimensionally *flows* originating from a surface object, e.g., vortex, always create a vector towards its interior (centripetal), making it an attractor. Expanding these types of flows to four-dimensional spacetime, we can dimensionally distinguish four types of flow forces (Box 3). If spacetime is a four-dimensional flow surface, what are the four types of *flows* constraining the surface? There is a direct correspondence between flows predicted by the framework and the four fundamental interactions of particle physics: *strong*-, *weak*-, *electromagnetic interactions* and *gravity*. In the ecosystem framework, interactions are defined by their dimensions of constraints. Fascinatingly, this appears to apply to the fundamental interactions of particle physics, making them a special case for elementary particles. Spacetime being a four-dimensional surface, we would expect four different types of forces governing interaction between objects (Box 3): one-dimensional force vectors (i1) acting between individual objects (matter-flow). The strong interaction corresponds to this characteristic by the flow of gluons creating a self-reinforcing interaction between quarks of the proton or neutron. Two-dimensional force vectors (i2) interact via surface gradients (energy-

flows), resulting in energy changes of objects. The weak interaction corresponds to this characteristic by mediating transformation of particles, resulting in surface radiation. Three-dimensional force-vectors (i3) interact via conformation changes (information-flows) by replication (sending and receiving) information. The electromagnetic interaction corresponds to this characteristic by using photon frequency exchanges to transmit conformation changes, such as the positions of electrons in an atom. Finally, four-dimensional force-vectors (i4) within a four-dimensional flow surface act attractive when being the result of an object (like a two-dimensional vortex vector on a river surface). They are spatiotemporally constrained (history-flow), and thus constrain how subsystems in the ecosystem of an object evolve. Gravity corresponds to this characteristic, as in not only attracts other massive objects but also affects how space and time act around a physical object (Einstein 1916). Fundamental interactions, together with elementary particles, give rise to all matter and are responsible for its consistent properties across known spacetime. Fundamental interactions are assumed elementary by the Standard Model (Robinson 2011). According to the framework, they arise as environmental *flows* of systems in chronous space, analogous to how planetary air and water flows constrain a river surface (Supplementary Information, Table S1). To find a common description for all particle-based objects, we need to explain how we get from four fundamental interactions to all physical objects and their processes, from atoms to hurricanes, viruses, and organisms.

Box 3. Particle-based spacetime interactions (*in: dimensionality of interactive constraint*)

matter-flow (i1): one-dimensionally (kinetic) constrained flows of systems or subsystems (acceleration constrained).

energy-flow (i2): two-dimensionally (surface) constrained flows of gradients (absorption/emission constrained).

information-flow (i3): three-dimensionally (conformation) constrained flows (replication/reproduction constrained).

history-flow (i4): four-dimensionally (spatiotemporally) constrained flows (adaptation constrained).

Environmental characteristics of generalized fundamental flow interactions

How do physical objects, self-reinforcing interaction patterns according to this framework, form and evolve in conventional spacetime? In theory, a self-reinforcing interaction pattern can form, de novo, from an equiprobable interactive environment (Kauffman 1986, Krauss 2012). However, as discussed above, any object embedded within the known universe is already subject to a pre-existing flow environment, constrained to four spacetime dimensions and subject to natural laws limiting propensities for pattern formation. According to the framework, natural laws are the result of fundamental interactions that prepattern the spacetime surface. *Flows* in Box 3 are named according to interactive properties in particle-

based objects, but characteristics arise because of dimensional geometry: *matter-flows* (i1) are point to point (kinetic) forces; *energy-flows* (i2) act via surface absorption and emission; *information-flows* (i3) are transmitted and received via pattern reproduction; *history-flows* (i4) act spatiotemporally by forming adaptive memories. Any self-sustained object in spacetime will result in such forces causally affecting their interior and exterior environments (Fig. 2A).

Figure 2. A. Force propensities generated by subsystem interactions of an object. *matter-flow* by individual subsystems; *energy-flow* by gradients of subsystems; *information-flow* by patterns of subsystems; *history-flow* by spatiotemporal evolution of subsystems. **B.** Hierarchical nature of propensity flows within the ecosystem of an object. *matter-flow*: force towards the environment by outflow of individual subsystems; *energy-flow*: towards system and/or environment by gradients attracting or emitting groups of subsystems; *information-flow*: towards system and or environment by emission or absorption of patterns of subsystems; *history-flow*: force towards system interior by attraction of potential subsystems and system process formation.

Actual flow expressions will manifest dependent on type of object and whether they act towards the interior or exterior of the object. When every object is part of an environmental ecosystem and its subsystem interactions form ecosystems themselves, flow forces act across nested hierarchies. But they create boundaries (Varela 1974) and forces will change characteristics as they act across those boundaries. For example, an atom is an object, internally constraining interactions between its nucleus and electron cloud. On the lowest level of its hierarchy, electrons interact using photons to exchange information/confirmation in the electron cloud via the electromagnetic interaction; in the proton, the strong interaction will emit gluons from quarks, the weak interaction allows for graded transformation of particles in the nucleus; and gravity, in combination with the Higgs scalar field, provides spatial (mass) and temporal (time) identity to all these processes. However, already at the level of the nucleus, there is a change in the flow forces mechanistic: The nucleus presents a unified identity to its environment that interacts with the electron cloud in the context of the atom. If internal disruptions occur, e.g., a radioactive decay of a neutron, characteristic properties of the atom will adapt and change, internally and externally. Conversely, if the outside environment changes, e.g., the atom becomes part of a molecule, the atom as an object will adapt its internal ecosystem environment towards finding a new stable state. In the view of the framework, forces crossing a hierarchy do

not change their geometric properties, but they can express themselves very differently, using any mechanism available. In fact, they are not mechanistically defined at all. For example, at the level of individual quarks, the strong interaction is a matter-flow force (i1) governing the emission of gluons, but at the level of the protein or the nucleus, the strong interaction is expressed as attractive history-flow force (i4). On the level of a planet, history-flow (i4) is using gravity to attract objects and make them adapt to its spacetime environment. In the context of a solar system, gravity is the expression of a matter-flow force (i1) that constrains acceleration. Inside a star, the weak force is transforming energy between atoms, acting as energy-flow (i2), but at the level of the star itself, the electromagnetic force is acting as energy-flow (i2), exchanging heat via its surface and as matter-flow (i1) ejecting mass. This may sound confusing, but this is because we try to use mechanistic properties to describe interactivity between objects, rather than trying to understand how and **why** objects interact, and what their interactive properties are. Objects form within, and/or participate in, environmental ecosystems because their own flow forces mutually beneficially contribute to this ecosystem. In this case “why” is more important than “how” because how these flow forces come about is not relevant to the interaction pattern of the ecosystem itself. An atom can support a molecule when its electron cloud can adapt to a shape that makes both more stable. Thus, flow forces are governed by geometric principles that express themselves across levels. Directionality too, is governed by principles across four-dimensional spacetime: *matter-flows* (i1), described by acceleration of subsystems always act bottom-up; *energy-* and *information-flows* (i2 and i3) act bottom-up by constraining resources and top-down by strengthening overlying self-reinforcing interactions; *history-flows* (i4), forcing subsystems to adapt, always act top-down (Fig. 2B).

Formation and evolution of particle-based objects

Elementary particles arise from fundamental interactions when conditions are favorable, like ripples emerging on a river surface. Particle-based objects form when flows perturbations of particles become self-reinforcing. They constrain random dissipation of components, via resonance, along one, two, three or four dimensions, creating the four types of system objects summarized in Box 4.

Box 4: Ontology of particle based-based objects (*sin: dimensionality of self-reinforcing constraint*)

matter-flow based objects (si1): based on one-dimensionally reinforced flows; self-reinforcing recurring interactions between point-like subsystems, e.g., material systems, such as atoms, molecules but also solar systems and galaxies.

energy-flow based objects (si2): based on two-dimensionally reinforced flows; self-reinforcing recurring interactions between massflow gradients, e.g., thermodynamic systems, such as chemical reactions, tornados, planetary cycles and star evolutions.

information-flow based objects (si3): based on three-dimensionally reinforced flows; self-reinforcing interactions between recurring pattern reproductions, e.g., viruses, gene replication, transcription and translation.

history-flow based objects (si4): based on four-dimensionally reinforced flows; self-reinforcing interactions between behaviors (spatiotemporally constrained flows), e.g., cell lineages, organisms, species and biological ecosystems.

Material systems (si1 - *matter-flow* based) reinforce interactions between individual components by creating resonance, or positive feedback, along a single flow dimension. This happens when subsystems spatially align objective flows along linear vectors. Resulting forces pull (accelerate) participating subsystems towards a stable state of relative rest. A system is considered stable when its objective characteristics do not causally change over recurring iterations along its *diachronous axis*, conventional time, for particle-based entities. When there are multiple stable systems/objects, their recurring *flows* interact with each other, eventually giving rise to diverse ecosystems - from atoms to galaxies. Two-dimensionally reinforced *energy-flow* based systems (si2) require massflows interacting with massflows of other systems to create resonant gradient interactions (thermodynamic systems). Such systems are stable when their subsystems are in equilibrium, a state of dynamically constrained acceleration and deceleration. Spontaneous emergence of three-dimensionally self-reinforcing *information-flow* based systems (si3) is more improbable and requires subsystems to align recurring perturbations along three flow axes, resulting in pattern-flow propagations. Such systems can form when sufficiently complex thermodynamic systems propagate and recurrently interact to form self-reinforcing pattern *flows*. Examples are genetic systems, which perpetuate structural information of DNA, RNA and protein sequences by constraining pattern *flows* of material-, thermodynamic- and genetic subsystems. Genetic systems are stable when subsystems are in homeostasis, a state distinct from either relative rest or equilibrium. Finally, *history-flow* based systems (si4), or social systems, emerge when stable genetic systems create recurring spatiotemporal *flows* (adaptive behaviors), increasing the likelihood for interactions to become self-reinforcing. Examples are bacteria colonies, uni- or multicellular organisms, sexually reproducing species and the global biological ecosystem. Such systems are stable when genetic subsystems are in an evolutionary stable state (Gould 2002) and evolve in dynamically recurring processes, e.g. transcription or translation in a cell, cell-divisions in organisms, or life cycles in

species. In more simple terms, material systems (si1) are attractors of matter, thermodynamic systems (si2) are attractors of energy, genetic systems (i3) are attractors of information and organisms (si4) are attractors of history (learning). Table 1A summarizes the properties and stable states of systems. Table 1B summarizes flow expressions originating in particle-based systems.

A

Object type	Causally constrained dimensions	Constrains flow of	Evolutionary action	Stable physical State	Environmental Disruption
matter-flow based	1	acceleration	resistance to dissipation	relative rest	kinetic impact
energy-flow based	2	gradients	free energy conversion	equilibrium	energy exposure change
information-flow based	3	patterns	pattern reconstitution or reproduction	homeostasis	conformation disruption
history-flow based	4	identities	purposeful adaptation	evolutionary stable state	identity disruption

B

	FLOWS			OBJECTS		
Type of Flow Constraint	Type of Interactions	Fundamental Interactions (elementary spacetime flows)	Matter-flow based (si1)	Energy-flow based (si2)	Information-flow based (si3)	History-flow based (si4)
Matter (i1)	Point to Point	Strong interaction	Particle interactions	Temperature	Linear Sequence	Movement
Energy (i2)	Gradients	Weak interaction	Particle Transformations	Energy Gradient	Signals	Motivation
Information (i3)	Patterns (Spatial)	Electromagnetic interaction	Field Interactions	Pattern Formation	Replication	Meaning
History (i4)	Spatiotemporal	Gravity	Acceleration	Feedback Loop	Selection pressure	Purpose

Table 1. Formation and characteristics of particle-based objects. A. Summary of evolutionary properties and stable states. **B.** Flow expressions of physical system types. (i) constraint dimensions of interactive *flows*. (si) dimensionality of self-reinforcing constraints.

Objects evolve towards a stable state of maximal fitness, not maximum efficiency

Two kinds of *causal effects* force systems to progressively change from or toward a stable state: a) self-reinforcement recurrently increases efficiency (mutual information) between subsystem interactions, mathematically described as *Ascendency* by Ulanowicz (Ulanowicz 1997). For most systems, efficiency cannot reach 100% because even small fluctuations could then result in a collapse of its self-reinforcing interaction pattern (Ulanowicz 1997). Healthy biological ecosystems appear to reach stability at around 40% efficiency, coinciding with states of maximum fitness (Ulanowicz 2009). Many material systems, like atoms or molecules, have efficiency levels much closer to 100% in their stable states. b) environmental disruptions perturb self-reinforcing interactions. Unless a system collapses completely, its self-reinforcing interaction pattern will generate propensities (directional forces) to return to the previously stable state or evolve towards a new stable state in accordance with altered environmental *flows* (Ulanowicz 2003). Systems can

also take advantage of adaption to dynamically pattern their internal ecosystem, forcing subsystems to recurrently adapt to environmental changes. With higher-dimensional self-reinforcement, dynamic changes become increasingly complex, giving systems agency over the evolution of subsystems with same or lower dimensional reinforcement, while at the same time allowing subsystems larger ranges of state changes without affecting stability of the higher-order system.

To demonstrate this effect, we can look at a rubber balloon filled with gas molecules in an atmospheric environment (si2). Properties of a rubber balloon in equilibrium can be described with a few simple characteristics, e.g., shape, temperature, type of gas molecules, pressure, and allow modelling responses to environmental changes. However, they do not allow modelling locations and movements of each individual gas and rubber molecule from which the balloon system emerges. Gas molecules will freely interact kinetically with neighboring molecules. If a property of the balloon changes, or a small hole disturbs the equilibrium, kinetic interactions will have to adapt across gradients but freedom of movement for individual molecules will barely be affected. This type of nested hierarchy creates a possible distinction between “natural” and “artificial” systems, as well as the terms “*evolution*” and “*development*”: *natural* systems rely on their own self-reinforcing interactions to form, propagate and resist dissipation in a probabilistic environment; *artificial* systems rely on causally constrained dynamic environmental changes to assist their developmental propagation and will break down without such adaptive environmental changes; *development* thus is system *evolution* constrained by dynamically adaptive forces of a higher-order system. This distinction may become important for the *development* of beneficial *artificial* intelligence.

Computational modelling and framework verification in particle-based systems

How could we computationally model formation, evolution, and interactive properties of objects?

Mathematically, flow surfaces are dimensionally constrained forces that locally limit state changes in an infinite dimensional Hilbert space (Young 1988), making changes directional rather than equiprobable.

Objects evolving within a flow surface further constrain interactive state changes to increase likelihood of their propagation via self-reinforcement. Ulanowicz calculates the strength of self-reinforcement within an ecosystem as *Ascendency* by summing up the mutual information (conditional Shannon entropy) of each recurring interaction between subsystems and multiplies this sum with the Total System Throughput (TST)

(Ulanowicz 1997). His model describes ecosystems via one-dimensional matter-flow arrows (Ulanowicz 1986), modelling biological ecosystems, with Ascendency (mutual information scaled by TST) corresponding to energy stored within the ecosystem (Ulanowicz 1997). To expand this description to a general model, *flows* could be described as probabilistic multi-dimensional tensors, and TST could be described by four-dimensional environmental tensors. TST corresponds to the prepatterned, dimensionally constrained, *diachronous space*, the flow environment in which the self-reinforcing interactions of a system are built. The concept of describing entities via flow surface perturbations is not unique to this framework. The *de Broglie-Bohm theory* (Bohm 1952), an alternative to the Copenhagen Interpretation of quantum theory (2002) proposes that particles interact with a pilot wave corresponding to the Schrödinger wavefunction. The formulation is experimentally strengthened by *Pilot-Wave Hydrodynamics*, featuring walking droplets on a vibrating fluid path showing quantum like behavior (Bush 2015). Ulanowicz's formulation, using conditional Shannon entropy, appears also consistent with the use of entropy fluctuations (mutual interactivity) to derive the bending of spacetime (Jacobson 1995). I do not suggest that such conceptual similarities can be directly applied to the framework, but they support the assumption that a mathematical formulation could be derived from existing formulations.

Another prediction of the framework is that during growth and development, or following an environmental disruption, systems will generate adaptive forces that guide subsystem development towards a respective stable state. Such forces act via top-down perturbations, expressed in material systems via acceleration, in thermodynamic systems via feedback loops, in genetic systems via selection pressure and in social systems via behavioral adaptation (Table 1B). Such perturbations could be represented by dynamic force vectors with one, two, three and four-dimensional constraints, respective of system type. If the model is correct, it should predict the causal relationship between changes in interactive properties and the adaptive forces that a system exerts onto its subsystems. Adaptive forces do not constrain all aspects of internal system environments. Atoms do not constrain every state of electrons; hurricanes do not constrain every movement of water-flows; genes do not constrain every nucleotide of a transcript; and a cell does not constrain every signaling pathway. Rather, adaptive forces set process boundaries (Fig. 1C), constraining propensities for state changes. Analogous to how a Schrödinger Wavefunction constrains propensities for particle interactions via the Hamiltonian (Carroll 2019), a wave function should exist for every type of system.

Relationships between systems and their objective properties should be governed by generally valid dimensional interaction principles. For any particular system, knowledge about interactive properties will increase with experimental perturbation of environmental *flows*. Conversely, knowledge about environmental *flows* increases with knowledge about evolution of each contributing component. Successfully modelling physical systems using the principles of the framework and validating such models with established descriptions should allow to computationally model systems in other flow surfaces, such as those based on mind and stories, described below.

Neural activity systems based on temporal interactions

Dean Buonomano argues that the brain acts as a kind of time machine, spatializing time in the process (Buonomano 2017). This is born out in ways that the brain synchronizes timings of multisensory information, sometimes arriving hundreds of milliseconds apart (Wallace and Stevenson 2014); the way we build a narrative from past and future events; and description of temporal events using spatial terms such as “long”, “far” or “short” and near” (Buonomano 2017). For neural activity-based systems viewed through the lens of the framework, this is literally true. Action potentials, building blocks of neural activity systems, propagate along axons, spatially, relative to conventional spacetime. When mental objects form, i.e., are identified in our mind, the associated neural activity is neither spatially nor temporally uniquely localized. What we perceive as present moments, emerge from activities in many spatial regions and varying timescales. How can unique object representations be built from instances of neural activity? Particle-based objects are built from particles propagating in time. Accordingly, we can view mental objects as built by causal instances, time points (spikes) traveling spatiotemporally along neurons and synapses. Analogous to how particles interact across spatial distances, instances can interact across temporal distances to form mental objects via coincidences (i1), duration gradients (i2), frequency replications (i3) and adaptive narrations (i4). How to visualize objects made from instance-based neural activity? The diachronous (flow) axis for mental objects is part of the conventional spacetime environment of the brain (neurons, axons, and synapses) but self-reinforcing interactions form in the temporal realm, orthogonal to conventional spacetime (Fig. 3).

Figure 3. Orthogonal flow surfaces for matter and neural activity systems in organisms. Organism behavior propagates temporally and interacts in spacetime *diachronous space*. Neural activity propagates in the *spacetime diachronous space* but interacts via temporal bending patterns in the spacetime *chronous space*, orthogonal to conventional spacetime.

Formation of the mental realm – an ecosystem based on temporal flow forces

Thus, from the viewpoint of conventional physics, formation, interaction and evolution of mental objects occurs via temporal interactions in spacetime *chronous space*, constrained by spike incidence, duration, frequency and adaptive memory narration: *incidence-flow* (i1) interacts via time point to point (timing) interactions; *duration-flow* (i2) interacts via gradients of time intervals; *frequency-flow* (i3) interacts via patterned points of time; *narration-flow* (i4) interacts via adaptive evolutions across time flow. Temporally patterned interactions between humans are so natural in everyday life that we do not think of them as being outside particle-based causality. However, it requires a nervous system for organisms to causally interact with temporal flows, which should become more obvious when discussing social story-based systems. In objects built on neural activity, which propagate spatially and interact temporally, temporal dimensions are the result of constraints that are as “real” as space dimensions for particle-based entities. Therefore, such interactive flows can build “real” ecosystems via temporal self-reinforcing interactions analogous to particle-flow based objects but evolve by sustaining “mental” identities in temporal space (Box 5). Their identity also gives rise to real objective qualities and forces that (temporally) perturb their environment.

Box 5: Neural activity-based flows and systems

FLOWS

incidence-flow (i1): one-dimensionally constrained - point to point spike propagation (spatial spike iterations).

duration-flow (i2): two-dimensionally constrained - fast/slow mass flow propagation (spike train iterations).

frequency-flow (i3): three-dimensionally constrained - spike pattern propagation (spike frequency iterations).

narration-flow (i4): four-dimensionally constrained - evolutionary propagation (progressive temporospatial changes across iterations).

OBJECTS

incidence-flow based (si1): one-dimensionally self-reinforcing interactions of neural spiking (coincidences).

duration flow-based (si2): two-dimensionally self-reinforcing interactions of spike train activities (feedback circuits).

frequency-flow based (si3): three-dimensionally self-reinforcing interactions of spike patterns (frequency oscillations).

narration-flow based (si4): four-dimensionally self-reinforcing interactions of recurring evolutions (self-refining memories).

We assume a four-dimensional ecosystem for the neural activity *diachronous space*. This is reasonable because the flowspace in which action potentials propagate is constrained by the organism, a social system that creates four-dimensional bending patterns into the *chronous space* of conventional spacetime. Within this flow surface, neural activity systems can in principle dimensionally represent interactive properties of all particle-based objects within a mental space, while not being limited by the rigid laws of physical space – allowing for loosened constraints when imagining, dreaming or hallucinating (Pollan 2018). In the language of Kant, they create the space and time of a four-dimensional representational frame (Kant, Meiklejohn et al. 1955). The representational frame is governed by neural activity instances creating propagating temporal flow forces along axons and synapses with “natural laws” selected by successful propagation of organisms. Objects forming and evolving within this mental space express real causal forces on the biological space, e.g. via neurotransmitter release (Loewi 1921), reshaping of axonal connections (Hubel and Wiesel 1965), attracting blood flow (Attwell, Buchan et al. 2010) or regulating hormone levels (Kriegsfeld and Silver 2006). When such actions increase propensity for survival and propagation of the organism, they also reinforce their own occurrence. Thus, mutually beneficial interactions between the mental and physical space can become self-reinforcing while creating objects that are both spatially and temporally constrained. If particle- and neural activity-based objects evolve in different ecosystems, what type of object is the result of their interactivity? The answer is: story-based systems that use neural activity- and particle-based subsystems as *process templates*. Before addressing such systems though, we need one more piece for the puzzle: an encoding mechanism for representations that act as object templates.

Encoding stories into process templates

Everyone has an intuitive sense of what stories are. From a systems viewpoint, they have several curious characteristics: they have a beginning and an end, but don't necessarily need to be told in the same order. They propagate in conjunction with a template, but can do so temporally (subsequent iterations), or spatially (book copies or cell divisions). They are not constrained to a particular space or time but recurrently evolve when environmental conditions are favorable. Their interactive characteristics can be maintained over iterations that vastly vary temporally (fast/slow evolution, order of sequence) or spatially (size and shape). If neither spatial nor temporal properties alone define a story, what constrains their self-reinforcing interactions and objective properties? A clue is found in comparing a story and a process in view of the framework. A

process is the result of a higher-order system constraining its propensities for formation, evolution and endpoint of *system evolutions* (Fig. 1C). Processes have no agency over their external environment. Each iteration is independent of previous ones, randomly exploring its *diachronous space*. Story iterations are subject to environmental constraints as well but additionally shape their environment to reinforce their own reoccurrence. Thus, a story is an evolving process that purposefully adapts its own *diachronous space*. It does so by creating an external object that represents its own process in another ecosystem environment. For example, oscillatory river surface ripples can create ripples on the riverbed, reinforcing occurrence of surface ripples (Moglen 2015). This is more extraordinary than it might appear. Surface ripple induced bending patterns create a ***process template*** within their *chronous space* (the particle-based riverbed) that prepatterns their own *diachronous space* (the water surface) for subsequent recurrence. Individual wave systems do not benefit from this action. Rather, upstream *flows* become influenced by downstream *flows*, recurrently reinforcing story patterns. Another example for story-based systems are genes, for which the biochemistry of replication creates stories represented in the sequence of its corresponding DNA. Like with river surface and riverbed, this requires interaction of two ecosystems: linear *sequence-flow* embedded in DNA, RNA or protein molecules and two-dimensionally reinforced *energy-flow* based biochemical reactions. Sequence *flow* propagates spatially along physical molecules to constrain location and patterns of thermodynamic propagation. It propagates within a one-dimensional flow surface that is outside physical spacetime but is constrained by thermodynamic systems encoding it into physical molecules. Like a human story, sequence flow is media independent with probabilistic building blocks. Self-reinforcing objects (genes) can be stored on DNA, transcribed into RNA, translated into proteins or analyzed by a human mind on a computer screen. Together, thermodynamic systems and an external sequence flow give rise to three-dimensionally constrained *information-flow* based systems: biological systems constrained by environmental selection pressure. Social systems expand self-reinforcement by one more dimension to constrain evolution across cell divisions and generations, with DNA templates representing adaptive processes. How can four-dimensional behavioral processes become encoded into linear sequences? I propose that this is achieved by causally modulating sequence arrangements along the four spacetime dimensions (Box 6).

Box 6: *Sequence flow modulations*

- (i1) **on/off** of encoding sequence (point to point),
- (i2) **length** of encoding sequence (constrained gradients)
- (i3) **conformation structures** of encoding sequence (constrained patterns)
- (i4) **adaptive replication** of encoding sequences (constrained evolutionary recurrences)

It has to be emphasized that representative *flow* modulations cannot arise from material systems (si1) alone, sequence being irrelevant to persistence of DNA molecules (Deacon 2012). Propagation of sequence modulation requires higher-order systems to actively/forcefully constrain entropic sequence randomization. According to the framework, templates in sequence space are the result of objective forces in particle-based spacetime. Template reinforced processes are referred to as a *story* and the *flow* structure encoded in templates as *representation*. Jointly, they form **story-based representation systems**. For biological organisms, sequence flows act as templates to represent potential stories of four-dimensionally constrained biological organism. Language, written or spoken, according to this interpretation, is another ecosystem flow surface, one that can encode mental processes via *narration flow* (Box 5).

Story-based objects from particle- and neural activity-based interactions

All biological organisms and species form and evolve their objective presence from recurring *history flows* (i4) and can constrain their own propagation via adaptive behaviors. They are story-based systems encoding adaptive changes over replications and even generations into linear sequence templates (Box 6). Template molecules (DNA, RNA or proteins) play a passive role in the encoding process, subject to top-down *flow* constraints such as rate and location of transcription. For mental representations, like concepts of objects, the situation is very different. Representations encoded via neural activity are themselves interactive, evolving, objects. Mental objects evolve within spacetime *chronous space*, four-dimensionally patterned by the nervous system, but dimensionally distinct from particle-based spacetime (Fig. 3). Conversely, neurons are part of a biological body and develop in an ecosystem that is temporally pre-patterned by neural activity. Multi-dimensional self-reinforcing *representations* can be encoded in the (external) *chronous* space of either ecosystem. For example, material objects can be encoded as sensory representations in the mental space. Abstract ideas can be encoded as works of art or tools in physical space. An example is the forging of a sword. Rather than direct manipulation of individual molecules, such as in 3D printing, a blade smith uses

mental representations to create dynamic heating and cooling processes that force molecules to adapt their natural dissipation into a desired shape (Hrisoulas 1991). What is the process for the formation of mental representations in particle space? Mental objects, such as ideas, use neural activity to temporally modulate behaviors of particle-based objects (Table 1, Box 3). In organisms with a nervous system this generally manifests via dynamic patterning of the motor system (Voudouris and Fiehler 2021). As a result, organisms add temporal dimensions to particle-based history *flows* (i4) expanding the interactive space by up to three additional dimensions (i7). Organism with a nervous system can then interact via higher-order *flows*, such as ideology, rationality and empathy to form higher-order social systems (Box 7).

Box 7: Matter-based *history-flows*, modulated by neural activity-based representation-flows

FLOWS

behavior-flow (i4): recurring flow of incidental behaviors, expressed via movement sequences, such as a mating ritual. Dimensionally identical to *history-flow*, *behavior-flow* can be purposefully perceived **and** expressed by organisms, while *history-flow* only acts inwards.

ideology-flow (i5): recurring flow of temporally graded behaviors, perceived and expressed via rhythmical mass movements, such as agitation or vocalizations.

rationality-flow (i6): recurring flow of temporally patterned behaviors, perceived and expressed via reproducible and informative movements, such as conveying directions, building instructions or artistic creations.

empathy-flow (i7): recurring flows of narration-based (dialectic) behaviors, perceived and expressed via adaptive behavior evolutions, such as narration of past and future events, or simulated system evolutions.

OBJECTS

behavior-flow based (si4): social systems built on self-reinforcing *behavior-flows*. They propagate via engrained (habitual or reflexive) behavior sequences, e.g., basic social communities such as tribes and family relationships.

ideology-flow based (si5): social systems that are built on self-reinforcing coordination-flows. They propagate by evolving their subsystems towards common goals, e.g., ideologically motivated communities.

rationality-flow based (si6): Social systems built on recurring self-reinforcing rationality flows. They propagate via structured evolution of subsystems, e.g., cities, countries and other law-based structures.

empathy-flow based (si7): social systems built on self-reinforcing empathy-flows. They propagate via behavioral evolutions informed by adaptive narrations (dialectic discussions), e.g., charities and globally adaptive structures.

When individual organisms form higher-order social entities, they become subject to their agency, as any individual in a city, company or organization can affirm. For humans, this is not necessarily a one-way street. Individuals can take advantage of the biological nervous system to modulate mental *narration-flow* (i4 - Box 5) via *particle-based* interactions (Table 1) giving rise to higher-order narrative processes, such as memories, desires, rational concepts and theory of mind (Box 8). Individuals can then use flow forces from representations to model and purposefully influence higher-order social systems and (Box 8).

Box 8: Neural activity-based *narration-flows*, modulated by matter-based representation-flows

FLOWS

event-flow (i4): recurring flow of perceptually modulated event narrations, expressed by remembering or imagining event occurrences.

synchronicity-flow (i5): recurring flow of motivationally modulated event narrations, expressed by desires and ideas about past and future occurrences.

correspondence-flow (i6): recurring flow of event narrations motivated by meaningful patterns, expressed by rules and structured thoughts of past and future occurrences.

realization-flow (i7): recurring flow of narrations modulated by purposeful evolution of past and future occurrences.

SYSTEMS

event-flow based (si4): narratives built on self-reinforcing event-flows, such as concepts of objects and occurrences.

synchronicity-flow based (si5): narratives built on self-reinforcing synchronicity-flows, such as concepts of emotionally graded occurrences.

correspondence-flow based (si6): narratives built on self-reinforcing correspondence-flows, such as concepts of rational relationships and rule-based occurrences.

realization-flow based (si7): narratives built on self-reinforcing realization-flows, such as concepts of adaptively evolving identities and occurrences, i.e., concepts of behaving organisms and their adaptive responses (theory of mind).

Representations in the transcendental frame of the mind

According to Tables 7 and 8, both, particle-based spacetime and the neural activity-based ecosystem can give rise to up to seven-dimensional representations, even though they themselves are constrained to four dimensions. This may seem counter intuitive. Why refer to modulated flows as part of their respective flow surface if they arise from modulatory interaction between both? How to visualize such higher-dimensional flows? Interestingly, it might be philosophy and psychology that can help us with this challenge. In the “Critique of Pure Reason” Kant proposes a four-dimensional spacetime representational frame for objects perceived via the senses (Kant 1787). This representational frame is subject to “*a priori*” laws created by a transcendental frame. In the viewpoint of the framework, the higher-dimensional flows introduced in Box 8 can modulate the representational frame to extend its dimensionality: *event-flow* (i4) can turn on or off such a frame, *synchronicity flow* (i5) can perturb temporal propagation via biological emotion or behavioral motivation; *correspondence-flow* (i6) can pattern the representational frame via reinforced meaning; *realization-flow* (i7) can fully shape the frame via purposeful evolution guided by understanding.

How can real, higher-dimensional objects, form in physical spacetime or the representational frame (narration-flow based) when they are considered four-dimensional surfaces? According to the framework,

systems do not arise from subsystems but from interactions between *flows*. Even though higher-dimensional *flows* discussed in Box 7 and Box 8 arise from modulation via their (external) *chronous space*, they manifest within their respective ecosystem. Their interactions will give rise to real objects that are higher-dimensional constrained, even though they are embedded in a lower-dimensional flow surface. On a river surface, it would be as if surface wave patterns form three-or more-dimensional entities that are part of the surface itself and subject to its two-dimensional constraints. In more human terms, think of works of art also having an emotional dimension, physical books conveying knowledge or a voice recording carrying dimensions of empathy. These are representations of ideas originating in the mental world but at the same time are subject to the physics of the particle-based world. Analogous to hypothetical higher-dimensional river waves, social systems forming from higher-dimensional particle-based *flows* (Box 7) are truly built on higher dimensional temporal and spatial constraints and thus can causally assert agency over systems based on lower-dimensional constraints. Like conventional particle-based systems (Table 1), subsystems of higher order social systems evolve towards distinctive higher-dimensional stable states: *behavior-flow* based systems (si4) are stable when a social group based on behavioral rules has achieved ***obedience***; *ideology-flow* based systems (si5) are stable when a group based on a common idea or goal (gradual development) attains context dependent ***certainty***; *rationality-flow* based systems (si6) are stable when a group based on recurring evaluation of certainties (facts) has gained ***knowledge*** (Wittgenstein, Anscombe et al. 1969); *empathy-flow* based systems (si7) are stable when a group based on adapting knowledge (truths) to mutual benefit have reached ***ethical understanding*** (Wittgenstein and Zamuner 2014). As with stable states in particle-based systems (Table 1A) there exists a nested hierarchy. Higher-order systems have to exert top-down forces to keep lower-order systems in a dynamically stable state: ***certainty*** requires feedback constraints of context-dependent models (Bayes 1763); ***knowledge*** requires selective replication of “certain” facts in a variety of contexts; ***ethical understanding*** requires dynamic adaptation of “knowledge” to achieve mutually beneficial interactions.

An ecosystem based on human stories

If higher-order social systems, like families, communities, countries, and global organization can be represented in the mental world, and ideas and mental concepts can be represented in the physical world, how can we philosophically, computationally and mathematically describe the combined space of these very

distinct ecosystem environments? The interactive space between two flow surfaces can again be illustrated by an example of the river surface: In certain circumstances, ripple formation on the surface can be reinforced by ripple representations on the riverbed to form an oscillating/self-reinforcing system (Moglen 2015). This example is comparable to the physical separation of material and mental spaces. Surface ripples interact with each other via *flows* on the surface and the wave patterns on the riverbed are shaped by particle-based interactions between water and ground molecules. To model self-reinforcing interactions between riverbed and surface waves, we need to consider two-dimensional *flows* propagating within the river surface (flow/wave interactions) and particle-based *flows* of water molecules causally involved in patterning the riverbed. According to the framework, their shared interactive space would need to be described as forming a flow space with two-dimensional surface waves modulating patterning of the riverbed, and three-dimensional riverbed patterns modulating surface waves. The resulting oscillatory system forms from self-reinforcing interactions between two flow spaces in which system entities can form and interact independently. If the model for ripple oscillation on a river surface can be mathematically expanded to the higher-dimensional surfaces of mental and physical world, it should potentially be able to act as basis for a computational model of a combined interactive space.

A philosophical model for the interaction between the physical and mental realm is offered by the *Quadruple Object* in Graham Harman's *Object-Oriented-Ontology (OOO)* (Harman 2018), in which *Real Objects* with *Real Qualities* in the physical space gives rise to a *Sensual Objects* with *Sensual Qualities* in the mental/neural activity space (Fig. 3A). The interaction between Real Objects and Sensory Objects causally occurs only via their qualities (phenomena). This is consistent with the framework presented here, in which objects are subjective/introspective entities (noumena) made from self-reinforcing interactions and only interact with other objects via force perturbations (phenomena) of environmental flows (Fig. 3B). This means that representations that form in the mental space, can only form from flow perturbations of physical objects (one or multiple) but never be identical to the actual objects. The converse is true as well. Representations that form in the physical space, like works of art, buildings or tools, can only do so via force perturbations (muscle movement via motor neurons) of mental objects (Fig. 3B). While this means that representations never directly conform to objects that they are representing, it is in the interest of the organism for mental representations to closely conform to the interactive qualities of physical objects. In other words, it is of

advantage for the survival of the organism to build an accurate representational frame to model its behavior in the physical world. According to the framework, selection of such a representational frame requires an overlying system with agency to create the natural laws for such a space. Such an ecosystem cannot be built from either domain alone but requires an interactional space made of both flow surface. This is different from most current models. OOO and to a certain extent also a *Naïve Realism* approach (Brewer 2011) presume that the reality of sensual objects depend on the reality of physical (real) objects. The framework introduced here arrives at a different model, that I propose to term *Objective Realism*, with the following assertion: once an object forms, its reality (objectivity) is no longer necessarily dependent on the reality (objectivity) of any other individual object. From the viewpoint of the framework both, physical objects (particle-based) and mental objects (neural activity-based) are equally real, in that they have real qualities that causally perturb their environment to interact with other objects. Further, I propose that interactions between physical and mental flow environments are constrained by a combined flow surface of story-based entities created by organisms with a nervous system, as discussed below for the environment of humanity (Fig. 3, Table 2). From a physics viewpoint, the framework is fully consistent with scientific interpretations of the world in which causality plays a primary role (Smolin and Bradonjic 2019), but extends scientific analysis of causal reality beyond the particle-based physical realm into the mental realm and the realm of stories.

Figure 3. Object-Oriented-Ontology vs Objective Realism Interpretations. A. Quadruple Object as proposed by Graham Harman. Objects are not interacting directly but via their qualities. Real Qualities give rise to a Sensual Object and Sensual Qualities causally interact with real objects. **B. Objective Realism.** Physical objects in the physical environment and mental objects in the neural activity environment are built on common geometric and probabilistic principles and interact through their qualities. Mental and physical objects also causally interact with, and are constrained by, equally real story-based objects within the human story environment.

Three worlds of Popper and three ideas of Kant

Philosophically, the interpretation has similarities with the three-worlds concept introduced by Karl Popper (Popper 1979), who differentiates between a material world (world 1), a world of mental processes (world 2) and a world of abstractions (world 3) that emerge from the mental world. However, there are key differences

with the three environments of this framework: real objects in the human story environment (Fig. 3B) can arise from interactions in physical and neural activity environments but the human story environment envelops the human associated physical and mind spaces like the biosphere envelops wave formation on a river surface, the shape of the riverbed, and the water flow connecting them. Furthermore, as discussed in the supplementary materials (Supplementary Information, Table S1), human stories may appear abstract and emergent, but I propose that the *flows* from which they arise are real physical fundamental interactions that are subject to laws of geometry and probability. Put into the context of Popper's model, real, physics-based natural laws of world 3 give rise to the materialism of world 1 and the idealism of world 2. Each world (ecosystem flow surface), even each object, arises from primary principles: *chronous* (causal flow probability, described by physics), *diachronous* (causal geometry, described by mathematics) and *kairos* (causal interaction, described by logic) and gives rise to objective qualities: Chronous (Time), Diachronous (Space) and Kairos (Present/Identity). Kant argues for a metaphysics (physics of the mind) based on natural laws of pure intuition (Kant 1787). As part of his framework, he proposes three transcendental ideas, *psychological*, *cosmological* and *theological*, each on their own giving occasion to a dialectic of pure reason. If we understand the term "dialectic" as "interactive space", the *ideas* can have a direct correspondence to the environments presented here: *psychological* – a representation of the mental space, *cosmological* – a representation of the physical space and *theological* – a representation of the story space.

First Principles of Objective Realism

In 1783 Kant placed a challenge to future Metaphysicists (Kant 1783): **How are synthetic propositions *a priori* possible?** He specifically gives the example of the equation " $7 + 5 = 12$ ", in which (5), (7) and (12) are abstract mathematical objects. In view of the framework, (5) and (7) are synthetic objects (propositions) with distinct individual objective qualities. If one creates a representation (sensual object) of (12), it would be impossible to determine that it came from the synthesis of (5) and (7). So how can we use *a priori* arguments of the framework to determine the synthesis? If we place the objects (5) and (7) into an environment that encourages addition, on a flow surface of integers, they will interact and resonate via self-reinforcement to give rise to a novel object (5,7,+) with the objective identity of (12). If we now causally change the environment, so that it encourages subtraction instead of addition, (5) and (7) will again interact but now resonate to form an object (5,7,-) with the objective appearance of (-2) or (2) at 50% probability each. If we

understand the *a priori* rules of the environmental effects on forming propositions and have agency over the environment, we can now conclude with certainty that (12) in the above example, was derived from the synthesis of (5) and (7). As required by Kant, we used only pure physics, pure mathematics and pure logic in the process (self-reinforcement is described by Shannon mutual information (Shannon 1948)). The framework thus creates a philosophical viewpoint that could be understood as synthesis between the *Speculative Realism* of Harman's OOO, the *Materialism* of Popper and the *Transcendental Idealism* of Kant, here termed "**Objective Realism**". See Box 9 for a summary of first principles that form the basis of this philosophical interpretation of the framework. These principles apply to objects in any flow surface of any dimensionality. The permanence of the principles allows representations across ecosystem flow surfaces to maintain consistent laws of object interactivity, formation, and evolution.

Box 9		
First Principles of Objective Realism		
Pure Physics (chronous)	Pure Mathematics (diachronous)	Pure Logic (kairos)
Laws of Variation	Laws of Geometry	Laws of Interaction
Objective Change	Objective Existence	Objective Observation
Probability	Constraint	Self-Reinforcement
Creative Flow (increase of mutual benefit)	Inertia Flow (decrease of mutual benefit)	
Formation (kairos)	Destruction (kairos)	
Evolution (chronous)	Dissipation (chronous)	
Constraint (diachronous)	Resistance (diachronous)	

Human agency via stories

What are human beings according to this framework? How do we express agency over mind and matter? Organisms with a nervous system use interactions between physical objects (the biological body) and mental objects (made of neural activity) to manifest a new flowspace environment in the interfaces between synapses and organism behavior (Damasio 2010). In this viewpoint, human individuals are story-based systems that use matter and neural activity flowspaces to create representation templates to propagate their stories. The actual flowspace in which they evolve is the ecosystem of stories, that emerges from the interactions between organisms. This flowspace manifests through interfaces created by sense organs and

motor systems, as well as their electronic and mechanical augmentations. Communication/interaction between individual human beings requires formation of *representation templates* in both, mental and physical domains: **a) mental templates** form via modulation of spike activity with biochemistry and manifest as memories, concepts of physical objects and even evolving concepts of other human beings (theory of mind); **b) templates in the matter domain** form via modulation of muscular motor behavior with neural activity giving rise to buildings, artwork and farming. The human body and human mind are at any moment dynamic representations; complex, up to seven dimensional representations, but still, like the DNA sequence of biological organisms, they are “only” encoded templates for propagation of the actual interactive story that is an individual human being. Humans, from this viewpoint, are stories that propagate and evolve in a 10-dimensional human story space (Table 2). This is possible because individual human beings can use both, mind and body to create combined representation of higher-order social objects, such as ideologies (si8), sciences (si9) and benevolence (si10).

To better visualize this, let’s take the river surface into the land of imagination: imagine a river surface with its own flow-constrained wave patterns influencing the climate of the planet. Then imagine the climate responding via adaptive feedback and reproducing patterns across regions to other river surfaces. Climate and river surface wave patterns, together, form a new ecosystem constraining evolution of subsystems in both flowspace. I argue that humans and humanity as a whole form such a “new” objective environment. Within this environment, templates for story processes can be made of mental concepts, physical objects, or a combination, to create higher order flow perturbations. Story flows can act as memes (Dawkins 2016) to elicit interactive *stories* in others, to give rise to complex higher-order objects within the human story environment. Using higher-order flows, individual humans gain agency over mind- and particle-based objects, allowing humanity to assert causal control over all aspects of the planetary ecosystem, while creating imaginary worlds in their collective minds. They augment their bodies with clothing and mechanical equipment and augment their minds with electronic devices that use temporally constrained electron flows instead of neural signals. The more complex the template structures, the greater the potential agency over types of objects. As with physical and mental objects, there is a nested hierarchy based on dimensional constraints. Story objects with higher-dimensional constraints assert agency over those constraining a lower number of dimensional flows (Table 2).

physical flows	physical object examples	neural activity flows	mental object examples	Story-object examples
(i1) matter	(si1) molecules			(si1) kinetics
(i2) energy	(si2) turbulences			(si2) thermodynamics
(i3) information	(si3) genomes			(si3) information theory
(i4) history/behavior	(si4) organisms	(i1) incidence	(si1) perception	(si4) reflexive behavior
(i5) ideology	(si5) communities	(i2) duration	(si2) emotions	(si5) vocalization
(i6) rationality	(si6) cities	(i3) frequency	(si3) thoughts	(si6) construction
(i7) empathy	(si7) charities	(i4) narration/event	(si4) identity/percepts	(si7) languages
		(i5) synchronicity	(si5) emotional concepts	(si8) ideologies
		(i6) correspondence	(si6) rational concepts	(si9) sciences
		(i7) realization	(si7) adaptive strategies	(si10) benevolence

Table 2: Proposed relationships between natural-, neural activity- and representation flows and systems. Orange shading indicates spatial interactions, blue indicates temporal interactions, purple indicates spatiotemporal interactions and green indicates mixed interactions between matter-based and neural activity-based flows. A more speculative version (Table S1) that includes proposed *elementary chronous flows*, is discussed in the [supplementary information](#).

As proposed above, dimensional constraints across space and time dimensions in the mental and physical environments result in up to 10-dimensional flows in the human story-based environment. Such dimensionality might sound intimidating, but the resulting story-based objects are part of everyday life in human society. In fact, I propose that formation and evolution of any story-based object type, including languages, ideologies, science and even benevolence can be modeled computationally. Understanding the reciprocity of self-reinforcing interaction patterns (si) and environmental flows (i) can allow to perturb, model, and study any kind of object. Humans do this naturally by creating stories from templates in the physical and mind domains and have them evolve models of each other by selecting for up to seven-dimensional aesthetic representations in either domain (see Box 7 and 8). More specifically, we apply agency by perturbing respective neural activity and material environments to select models for corresponding interactive and evolutionary properties. Resulting models are then used to perturb the environment of external objects to our advantage. Modelling is possible because evolution and interactive characteristics are subject to first principles of dimensionally constrained *flow* interactions (Box 9). The more accurate the model, the higher dimensional agency we attain over evolutionary propagation. Agency does not constitute “free will” in the strictest definition (Carroll 2016). Propagation is always subject to bottom-up flows required for self-reinforcing interactions, but better models result in more control over such *flows*. **Benevolence** as highest order flow in this framework, in principle, allows a system to adapt its inner environment for mutual

benefit to itself and individual subsystems across all dimensions of the human story-based flow surface.

Summary and Appeal

The framework introduces a simple principle, *dimensionally constrained self-reinforcement of pre-existing flows*, to create a general description for particle-, neural activity- and story-based object evolution. Once computational models are formulated, the framework can be validated or falsified via existing models in physics, as well as data from socioeconomic systems, such as development of cities, countries and organizations. A testable hypothesis in the field of neuroscience might be its prediction that percepts and mental concepts are real interactive objects built from multi-dimensional temporal constraints (incidences, duration, frequency, events). This should differentiate it from current computational models, such as deep learning, built on coincidental spatial reinforcement (adaptive synaptic strength) (Goodfellow, Bengio et al. 2016). Philosophically, the framework has a mathematically and computationally tractable answer to the problem of consciousness: human consciousness is the agency to create interactive representations of matter-based objects in the neural activity-based ecosystem of the mind, and vice versa. A conscious agent, e.g., a human self, is a story-based object, sustained by spatially constrained representations (material or biological objects in the matter space) and temporally constrained representations (ideas or concepts in the neural activity and/or electronic space). The framework has also ethical implications: Tim Morton argues in *Humankind* (Morton 2017) for a solidarity with non-humans, and for life to exist as part of the Symbiotic Real. Here, I similarly argue that human beings are naturally built from self-reinforcing (mutually beneficial) interactions between the mind (neural activity) and matter (physical) domains; and that our reality is made of ecosystems of stories symbiotically interfacing with these domains. Humans are surrounded by ecosystems of vast hyperobjects (Morton 2013), currently beyond the grasp of sensory perception. The framework proposes that humans too are hyperobjects. With the ability of the human self to create models from mind and matter, individuals have agency to mold objects, events and processes to the mutual benefit for themselves and their environment, squarely returning potential agency over and responsibility for the environment back to humans. Unlike parasites which destroy the environment for their benefit, we can be benevolent symbiotes, improving our environment, while reinforcing our own propagation. The author hopes that the framework presented here can shed light on this agency. As human beings, we have the potential to

achieve full mastership (agency) over mind and matter, but we also rely on their dynamic existence, complexity and beauty to propagate our stories.

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Supplementary Information

elementary flows	matter-based flows	matter-based system examples	Neural activity flows	neural activity-based system examples	Human story-based representation system examples
(i1) strong force	(i1) matter	(si1) molecules			(si1) Newtonian physics
(i2) weak force	(i2) energy	(si2) turbulences			(si2) thermodynamics
(i3) electromagnetic force	(i3) information	(si3) genomes			(si3) information theory
(i4) gravity	(i4) history/behavior	(si4) social systems	(i1) incidence	(si1) perception	(si4) reflexive behavior
(i5) time	(i5) ideology	(si5) communities	(i2) duration	(si2) emotions	(si5) vocalization
(i6) light	(i6) rationality	(si6) cities	(i3) frequency	(si3) thoughts	(si6) construction
(i7) objective identity	(i7) empathy	(si7) charities	(i4) narration/event	(si4) identity/percepts	(si7) languages
(i8) objective transformation			(i5) synchronicity	(si5) emotional concepts	(si8) ideologies
(i9) objective knowledge			(i6) correspondence	(si6) rational concepts	(si9) sciences
(i10) objective understanding			(i7) realization	(si7) identity concepts	(si10) benevolence

Table S1. Proposed relationships between natural-, neural activity- and representation *flows*, including higher-order *elementary chronous flows*.

Proposed higher-order elementary chronous flows.

The ecosystem framework introduces a physics perspective for mind and self but has the potential to expand our viewpoint of physics itself. Particle physics is based on four fundamental interactions, and some suggest the higgs field, with higgs bosons as force mediators to be categorized as a fifth fundamental interaction (). The framework does not start from the standard model of particle physics, but rather defines fundamental interactions by their interactive dimensionality. Interestingly though, the ontology of the fundamental interactions of particle physics appears to be consistent with the more general ontology of dimensionally defined interactions of the ecosystem framework. According to the framework, fundamental interactions are flows that arise in the *Chronous Space* of spacetime and act to constrain the spacetime flow surface environment. This does not mean that these flows arise outside our universe. On the contrary, as discussed in the main article, even physical objects, mental objects, and story-based objects arise from flows that are higher-dimensionally constrained than the four dimensions of spacetime. In the view of the ecosystem framework, the spacetime surface, akin to a river surface provides a four-dimensionally constrained ecosystem for particle interactions. If we propose that the story-system is an at least 10-dimensional flow surface, what are the fundamental forces in our universe that constrain such an ecosystem? Table 1B refers to the four fundamental interactions of particle physics according to their manifestations of spatial interactivity between elementary particles. If we take a closer look at their type of

interactions, they can be described as temporally constrained, just as neuron would constrain a muscle cell:

- **strong force (i1):** gluons traveling spatially between quarks create coincidences binding quarks together.
- **weak force (i2):** sequential boson transformations create duration gradients resulting in timed radiation.
- **electromagnetic force (i3):** photons consist of sequential frequencies that are reproduced by objects.
- **gravity (i4):** gravitational waves are narrative sequences that carry the spatiotemporal history of events.

Using the dimensional characteristics of story-based objects (Table 2), we can propose additional fundamental forces that are dimensionally perturbed because of object interactions (Table S1):

- **time force (i5):** Just like gravity creates a consistent flow within a river surface, to manifest a flow along one of the dimensions of spacetime, there should be a higher dimensional force acting onto it. As I mentioned before, the higgs interaction, which attributes mass to particles via the higgs boson, and thus bends spacetime into a fifth dimension () fits the characteristics expected from such a fundamental interaction.

However, in the ecosystem framework, the dimensional action is more relevant. What would such a force flow look like in the human story verse? Interestingly enough, there is a simple example: the production and perception of object originating sounds. We perceive sounds as temporal changes in air pressure (i2) but object originating sound is also patterned in the three space dimensions (i3), resulting in a five-dimensional flow interaction that can be used for communication via vocalization (si5).

- **light force (i6):** light as emitted from an object combined temporal frequency information (i3) with a spatial distribution pattern (i3), resulting in a flow that carries six dimensional constraints when perceived or communicated via visual means (si6).

- **objective identity force (i7):** When objects are perceived via multisensory perception, the result is a temporally adaptive narration flow (i4) that is distributed spatially (i3) by the object itself, allowing objects to use this flow to communicate or to perceive the cohesive identity of another object. Spatially patterned narration flow is also purposefully used by humans communicating via spoken or written language.

- **objective transformation force (i8):** this flow carries the past and predictive (probabilistic) information about future developments of an object in a specific environment. In physics, this flow could carry the coherent quantum wave form of an object. Humans use this flow to communicate believes by adding emotional relevance to their communication.

- **objective knowledge force (i9):** this flow carries the information required to fully reconstruct the unique state of an object in any environment. In physics this could carry decoherence information of a quantum

state, as used in quantum computing. Humans use this flow to communicate and perceive facts and knowledge via the scientific method of rational analysis.

- **objective understanding flow (i10)**: this flow carries the information on beneficial development of an object, i.e., not only to represent an object but also how to create a dialectic interaction environment that is of mutual benefit to the objects interacting. Humans use this flow to communicate with empathy and benevolently with other beings.

In summary, I argue that the proposed elementary chronous flows are indeed part of physical reality that can be tested and validated. Moreover, understanding, perception and interaction with such flows may be essential for developing artificially intelligent systems that can interact with human beings and their environment in a mutually beneficial manner, while being subject to their natural constraints.