Systems Theory from a Cognitive and Physicalist Perspective (4).

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Abstract.

This paper, originally published in January, 2023, has been updated to include observations from:

a) “A Conceptual Framework for General System Theory”, John A. Challoner, Rational-Understanding.com, March, 2024.

b) “Different Interpretations of Systems Terms” sent to the Research towards a General Systems Theory SIG of the International Society for the Systems Sciences’ in April, 2024.

c) “The Mathematics of Language and Thought” (Challoner, 2021).

The paper discusses systems theory from a cognitive and physicalist perspective. The cognitive perspective holds that we are our minds and cannot escape the constraints imposed by their biology and evolutionary history. Nevertheless, human cognition is a reasonably accurate representation of reality. Physicalism holds that space-time comprises the whole of reality and that everything, including abstract concepts and information, exists within it.

From this perspective, conceptual and theoretical frameworks for systems theory are proposed and described. Concepts include: the importance of structure; the nature of relationships, causality, and physical laws; and the significance of recursion, hierarchy, holism, and emergence. Human cognitive factors are also discussed, including: their limitations; the nature of information and language; and the search for knowledge in a world of complexity and apparent disorder.

The paper includes the implications of this perspective for General System Theory and Social Systems Theory, suggesting further work to advance those disciplines.

1. Introduction

This paper discusses systems theory from a cognitive and physicalist perspective.

The German-American psychologist, Ulric Neisser, sometimes referred to as the father of cognitive psychology, defined cognition as "those processes by which the sensory input is transformed, reduced, elaborated, stored, recovered, and used." (Neisser, 1967). The cognitive perspective holds that we *are* our minds and cannot escape the constraints imposed by their biology and their evolutionary history. *We cannot escape our humanity and must understand its nature if we are to understand the world we inhabit.*

Physicalism is a form of philosophical realism. Realism maintains that things exist beyond the mind. However, physicalism takes this a step further, and holds that everything, including abstract concepts and information, exists in space-time. For example, justice comprises all just acts, and all just acts are events that occupy space-time. Information is matter or energy with an organised structure and matter and energy do, of course, occupy space-time. Examples include letters on a page, electrical pulses on the internet, and neural connections in the brain.

Cognitive physicalism holds that space-time and the entities it contains combine to form reality. It also holds that, with exceptions, our direct experience of reality is a reasonably accurate representation of it. Human cognition has evolved naturally through random mutation and natural selection. If it did not represent reality reasonably accurately, then it is unlikely that our species would have survived and become as successful as it has. However, evolution cannot predict the future.

In this context, “direct experience” means averages around which most of us cluster in the functioning of our senses and in our interpretation of their inputs. There are, of course, individuals who deviate significantly from these averages and whose perception of reality may, therefore, be incorrect.

Other exceptions to the accurate representation of reality include, firstly, inherited biases which enable us to respond to threats and opportunities quickly and without conscious thought. In general, these are survival characteristics, but individual instances do not always result in a successful response. Biases can also lead to errors. For example, they are a cause of our belief in the super-natural, the transcendent, the metaphysical, and other realities inaccessible to the senses. Secondly, information not acquired directly from physical reality, but obtained via third parties can be false.

The cognitive aspect of this philosophy also recognises that human beings have a finite capacity for perception and cognition. Because the universe of space-time is probably infinite, to understand and explain it we must simplify it. So, physicalism enables us to establish a single conceptual framework, but cognition limits our understanding and perception.

This paper proposes deep conceptual and theoretical frameworks that unify many of the concepts and theories of systems and which may form the basis of a General System Theory. It draws on the author’s twenty-five years of experience in unifying the various branches of logic, mathematics, and natural language into a single consistent system (Challoner, 2021) and on his current development of a unified theory of society (Challoner, 2024).

For the purposes of this paper, a “conceptual framework” is defined as a set of definitions of abstract words that is internally consistent. A conceptual framework comprises our understanding of these words and the universe that they represent. A “theoretical framework” is defined as a set of theorems, each of which can be proven from a set of axioms. These axioms are self-evident truths among which no contradictions exist.

2. The Nature of Theory

Theory applies not to isolated things or entities, but to the characteristics that they have and to the relationships between them, including causal relationships.

If, for example, we boil a kettle, we can observe it, create a visual image of it, give it a name and speak that name to someone else. However, when we say the word “kettle” we do not convey anything meaningful to that person. They may believe that there are gaps in what we say and may interpret our utterance as “Pass me the kettle, please.”, but that would be a personal interpretation of the meaning that they think we are attempting to convey.

On the other hand, if we were to say “The kettle is silver.” or “The kettle is boiling some water.”, then we *are* conveying meaning. The fundamental component of meaning in natural language is a sentoid of this type, rather than a word. These sentoids describe a characteristic of the kettle or its relationship to some other entity. The same is true of theory. It is a meaningful model of reality and does not apply to isolated entities, but rather, to their characteristics and relationships with one another.

So, there is a reality that comprises physical entities, their characteristics, and the relationships between entities. I will refer to this as "information at source". Any theory is a translation of information at source into a form that we can mentally manipulate, for example, visual imagery, natural language, or mathematics. The difficulty in developing a theory that we can all agree on is that we carry out our translations individually and that parts of those individual translations may be incorrect or incomplete. In the case of physical objects, we can perceive them in their entirety at a glance. Thus, we share the same information at source, and so, our various translations are much the same. The word “kettle”, for example, means much the same thing to all English speakers. However, in the case of more abstract entities such as “justice” and “conflict”, because they are discontinuous and comprise several components often widely distributed across space-time, i.e., acts of justice and conflict, we can only perceive a subset of those components. So, translations differ, often considerably. Furthermore, we translate into different forms. For example, we may use different words for the same thing or the same word for different things. To make sense of the world we can also rationalise without reference to observed reality. Finally, we distribute our interpretations to others who may have no empirical experience. Thus, our interpretations of abstract entities can differ widely and, if we write an abstract word, then the reader may interpret it entirely differently to the way that we had intended. Thus, it can be difficult to communicate, especially when we are discussing more abstract concepts that we can only partially observe in the real world. The net result is that things can seem more complex than they actually are, and we do not recognise, for example, that holons and systems are the same thing. This problem can, of course, be overcome if we are always careful to define abstract words whenever we use them.

So, the development of any theory first requires a conceptual framework to define the entities under consideration. It then requires a theoretical framework to explain the relationships between those entities.

Conceptual and theoretical frameworks both vary greatly in their depth and nature. As a rule, the broader the applicability of a theory, the deeper its frameworks must be. The deeper a conceptual framework, the more fundamental and general the words it defines. For example, the word “relationship” is very deep and has broad application, whilst “unhappiness” is far less so, applying only to human beings and some animals. The deeper the theoretical framework, the more fundamental its axioms. For example, the axiom “a statement cannot be both true and untrue” is very deep and has broad application, whilst the axiom “every system requires a control component” is far less so, applying only to living things and some of their artifacts. Clearly, because a General System Theory would have very broad and possibly even universal applicability, its axioms and definitions must be very deep indeed, probably to the point of appearing naive.

Without agreement on conceptual and theoretical frameworks, we can construct increasingly complex theoretical structures on very weak foundations, there will be no agreement on the theory, inconsistencies will arise, and natural selection will have to take its course. This means that those theories that serve us best will survive and propagate, irrespective of whether they are true, and those theories that do not will eventually expire.

3. Theoretical Frameworks

The author’s work on symbolic logic will be used as an example of a theoretical framework (Challoner, 2021).

Conventional symbolic logic is in a similar state to systems theory today. It comprises numerous disparate branches and a plethora of different symbolisms for each concept. This causes much confusion. So, over 25 years ago, he embarked on a project to unify these branches using a single common symbolism. Not only was this project successful, but it went on to include the unification of both natural language and mathematics.

Part of the project involved the axiomatization of logic, i.e., the identification of several axioms or self-evident but unprovable truths upon which all the remaining theory was based. It was necessary that these axioms provide an explanation of all generally accepted laws of logic. Symbolic logic was found to be *almost* self-defining. All its theorems were found to arise from the operation of its axioms on themselves. The only exception was the physicalist axiom, without which a unified framework would not have been possible. As each branch was unified, many conventional axioms were found to be theorems that could be derived from deeper and more general axioms. Nevertheless, a small number that were particular to a branch always remained to distinguish it from other branches. That is, every branch always had its emergent properties.

An analogy can be used when considering a general system theory. Providing they have an empirical basis, two theorems can be likened to minor branches of a tree. If we are aware only of the branches but not the tree, then they may appear to be unrelated to one another. However, if we can identify common truths that explain both ideas, then we have identified the larger branch from which the minor ones sprout. That is, we are beginning to perceive the tree. In this analogy the common truths are, temporarily at least, the equivalent of axioms. This process can continue until we reach the trunk of the tree. The more theorems we can unify in this way, the more likely the truth of their common explanation or axiom.

The truth of an axiom is not guaranteed of course. During the author's project, axioms frequently had to be revised as new branches of logic were incorporated. Considerable objectivity, patience and persistence were needed, therefore. Furthermore, in the case of general system theory there is no certainty that the tree does ultimately have a trunk and that there are universal axioms.

4. Main Concepts in Systems Theory

This section describes many of the main concepts in systems theory and the axioms or theorems associated with them.

Whatever else we may disagree on, we probably all agree that the universe is consistent, i.e., that no part of it contradicts any other. So, if the components of our understanding of the universe and the words that we give to them are inconsistent in some way, then there is probably an error in our understanding. It is important therefore that our definitions of words be mutually consistent too.

We also probably all agree that an emergent property is a property that a system has, but that it its parts do not. However, much of the terminology used in systems theory means different things to different people. Examples are given in the sections below, one of which is drawn from the Holism SIG of the International Society for the Systems Sciences. The definitions marked as "(Preferred)" have the advantage that they are all mutually consistent. They also explain much of what we observe empirically.

A. Space-time

The concept of space-time was first proposed by the German mathematician, Hermann Minkowski (Minkowski, 1908). It is a single continuum comprising three dimensions of space and one dimension of time. Within space-time there is a complex flux of matter and energy, the parts of which constantly interact with one another and change state, much like a river in flow.

B. Physical entities

Alternative definitions of "Physical" include:

- Any matter existing in a region of space-time.
- Any matter or energy existing in a region or regions of space-time. (Preferred)

Alternative definitions of "Entity" include:

- Any concrete physical thing. Abstract things may be deemed metaphysical.
- Any concrete or abstract physical thing, including characteristics, relationships, and events. (Preferred)

Physical entities can be represented diagrammatically using a simplified space-time diagram, such as the one below, in which the three spatial dimensions are condensed into one.

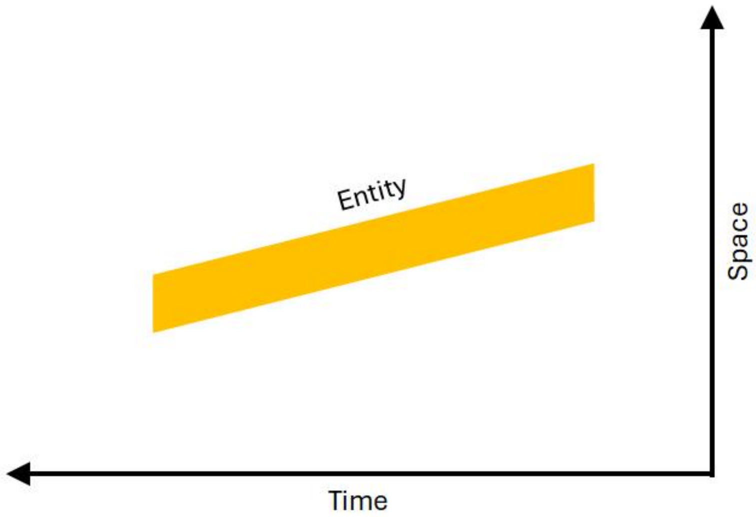


Figure 1. A Space diagram showing a single entity.

The entity is shown as coming into existence, travelling through space, and finally, ceasing to exist.

C. Meaningful entities

There is no meaning inherent in the physical world. Rather we make meaning for ourselves, and every individual does so in their own way. This is explained well in the following article

https://harishsnotebook.wordpress.com/2024/04/06/absurdity-in-systems-thinking.

An imaginary boundary or boundaries can be drawn around an entity separating what it is from what it is not. This boundary is subjective and defined by the human observer. However, we do not draw our boundaries randomly. Human beings have very strong pattern recognition skills (Eysenck & Keane, 2003). That is, an ability to recognise structure, organisation, or order in an entity. This is almost certainly an evolved trait because it is held by many other animals.

When we perceive structure, our cognitive processes cause us to draw an imaginary boundary that contains and maximises that structure. A bus, for example, is perceived as a single entity rather than two or more. We do not split structure in that way, unless there is good reason to do so. Nor do we include the air around the bus and the road beneath it because they can change and are not part of the structure that we perceive.

There are infinite ways in which an entity can be disordered. The likelihood of us experiencing the same disorder more than once is therefore very small. However, the number of ways in which an entity can be ordered is finite, and so, recurrences are more likely. We also have an evolved ability to recognise such recurrences. To continue the river analogy, we recognise vortices not only because they have structure but also because they recur relatively frequently. This is a survival trait that enables us to predict the behaviour of entities from experience.

In summary, therefore, entities that are meaningful to us are those in which we recognise structure and that recur. We symbolise meaningful entities by, for example, creating a mental image of them or naming them.

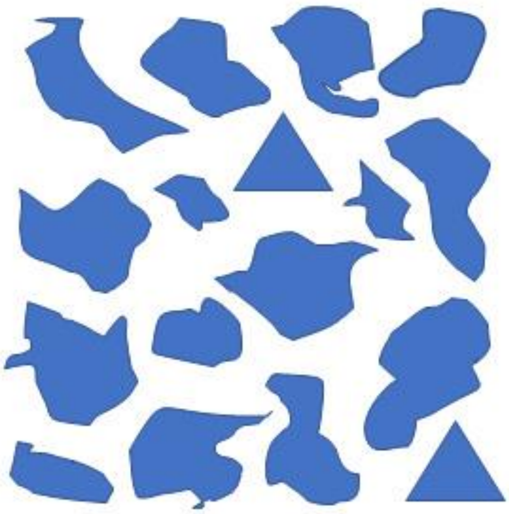


Figure 2. What do you notice about this image?

D. Metaphysics

Alternative definitions of "Metaphysical" include:

- Based on abstract reasoning.
- Not existing in space-time. i.e., not physical. (Preferred)

Many people believe that there is also a spiritual aspect to nature, and so, reject physicalism. The source of this is probably an unconscious sense that we use emotion in our decision-making processes. It is certainly true that we rely heavily on the unconscious mind and on emotion when making our decisions. This is something that we have inherited from simpler organisms and that evolution has built upon. From an evolutionary perspective, this is entirely reasonable, because the emotional and rational aspects of our minds work together to our benefit. However, in the absence of a rational scientific explanation for something, that thing can take on a mystical flavour, suggesting an alternative to our other skill, conscious rationality.

So, we often use metaphysical explanations when we are unable to identify physical ones. However, they have no supporting empirical evidence, and are therefore arbitrary rationales far more likely to be incorrect than correct. They should be avoided therefore and, where they already exist, should be abandoned in favour of physical explanations which have supporting empirical evidence.

E. Sets, collections, aggregation, and disaggregation

"The Mathematics of Language and Thought" (Challoner, 2021) employs a modified version of set theory that reflects systems theory and is consistent with it. Conventional set theory treats the set as a single entity. The modified form treats it either as a singular entity or as a plural collection of components. Furthermore, every individual entity or component can be disaggregated into component parts and every collection of entities or components can be aggregated into a single entity. The book provides equations that describe these processes.

F. Abstract entities

Alternative definitions of an abstract entity include:

- Existing in thought or as an idea but not having a physical or concrete existence.
- A physical entity with a boundary that is discontinuous in space time. Those parts contained within a continuous boundary are separated and distributed in space-time such that we cannot observe the entity in its entirety. (Preferred)

All abstract entities are physical. The only difference from a concrete physical entity is that an abstract one has a boundary that is discontinuous in space-time, and so, the entity is discontinuous in the same way. Thus, we cannot observe it in its entirety, and it is, therefore, more difficult to visualize.

Abstract entities can however be disaggregated into those component parts that are continuous in space-time. These are known as instances. This is reflected in natural language. For example, "conflict" comprises several instances of conflict, each of which is referred to as "a conflict". We can perceive several instances of conflict but not "conflict" in its entirety.

Despite having common features and aggregating together into a single abstract entity, the individual instances may also have features that are unique to themselves. This presents a communication problem. Each observer, a diplomat and a family counselor for example, will observe a different subset of conflicts, and will form a different understanding of the concept. So, when one is discussing the topic with the other misunderstandings are almost inevitable. Worse yet, different observers can give different names to the same thing in different contexts. This can make communication between the two difficult, if not impossible. It can also obscure the fact that they are discussing the same concept.

G. Characteristics or properties

A group of more than one entity forms a collection. Collections differ from sets in that they are plural in nature, whilst sets are singular. Characteristics are used to draw entities together into collections. So, any feature that the members of a collection hold in common is known as a characteristic or property.

Because characteristics recur in a number of entities, we give them a name. However, we cannot observe characteristics in their entirety, and so, we regard them as being abstract. They are of course physical and anchored to space-time by the entities that possess them. However, they follow different rules to those of physical objects. For example, the characteristic "coloured" is a sub-characteristic of "blue". On the other hand, "coloured entities" are a super-set of "blue entities". In "The Mathematics of Language and Thought" (Challoner, 2021) a characteristic is therefore defined as the aggregate of everything that does not have it. This definition enables characteristics to be logically manipulated in the correct way. However, it means that, although physical, they are impossible to visualise. We can only do so using examples of entities that have them.

H. Relationships

Usually, to depict a relationship we use an arrow between the two related entities. However, this image can be misleading. A relationship is not something separate and distinct from other physical entities. Rather, it comprises the two related things for so long as the relationship applies, together with anything transferred from the one to the other and vice versa, whether it be space, matter, raw energy, or information. Thus, a relationship is also a physical entity, albeit one comprising parts which may be separated in space-time. The nature of the relationship is the nature of the conjunction of those parts.

This also implies that all entities, even physical objects, can be regarded as relationships, albeit reflexive ones.

Because a relationship is a physical entity, like any other there can be relationships between it and other physical entities. For example, a hammer striking a nail can produce a sound that someone hears.

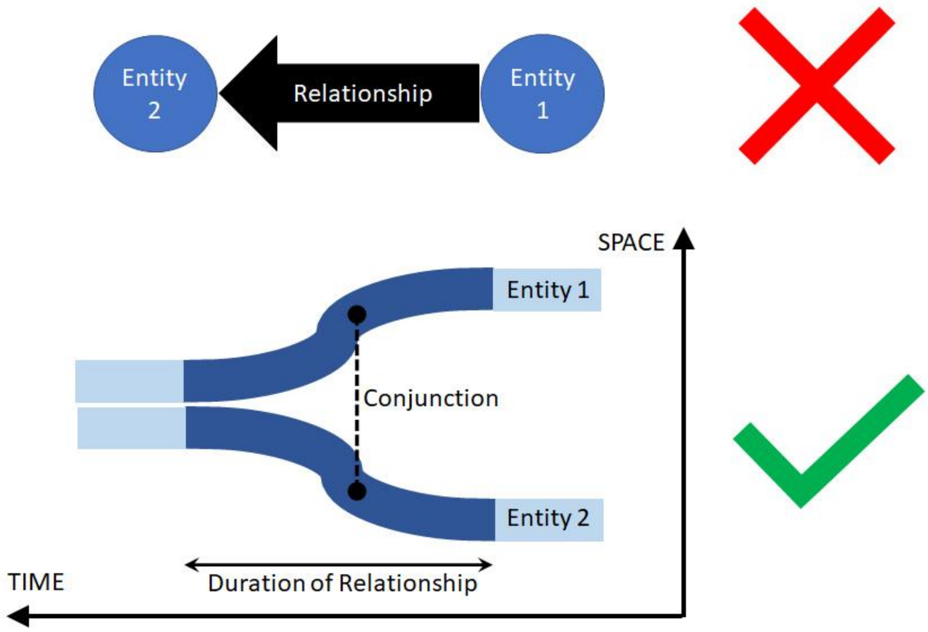


Figure 3. The physical nature of relationships.

Individual relationships have a simple recognizable structure and almost certainly recur. They are meaningful entities, therefore. However, they are not necessarily systems because they do not necessarily have emergent properties.

There is a question over whether the appearance of two related entities is an emergent property, i.e., a property that the relationship has, but that its component parts do not. If so, then all relationships are systems because they have emergent properties. If not, then a relationship is not a system. In this paper, I will assume the latter, i.e., that the appearance of an entity is not an emergent property. However, it should be borne in mind that this assumption is not necessarily true.

The assumption implies that there must be a minimum number of relationships between component systems before a higher-level system is formed, i.e., before a property other than a change in appearance emerges. This emergent property can be an output from the system, which in turn, can be the basis for relationships between higher level systems.

Relationships form networks. The more relationships in a network, the less likely it is to have a recognizable structure that recurs. So, the less likely it is to be a meaningful entity and the more likely it is to appear chaotic.

I. Events

Events are physical entities. They are spatio-temporal relationships. That is, something earlier doing something to something later. So, an event comprises the two entities together with whatever passes between them.

J. Emergent properties

As physical entities are progressively aggregated, new features, characteristics or properties emerge. An emergent property is a feature or characteristic of a physical entity that its component parts do not have.

K. Holism

Alternative definitions of "Holism" include the following.

- The Holism SIG of the International Society for the Systems Sciences has published the following alternative definitions of Holism:

  "1. Basic Holism

  There are three basic definitions of holism.

  a. Universe Holism argues that since everything is related to everything else the only true whole is the Universe of all and everything.

  b. Materialist Holism or Both/And Holism defines a whole as a collection of things. It consists of a list of things and is called holistic if it includes all the items on the list. The original concept was of a set of material objects, but it has been expanded to refer to anything that can be put on a list. The whole is a set and is equal to the sum of the parts.

  c. Logical Holism or Either/Or Holism defines a whole as an idea. Because it is an idea, it has a definition, a boundary that distinguishes between the whole and its context. It is the logical element either/or, a difference that makes a difference. Because it has a boundary it has an inside and an outside. The parts of the whole are inside the whole and are defined by their relationship to the whole which is the context for the parts. The whole can be a part of a larger whole. This dual aspect of logical wholes is called a "holon," and the hierarchical structure of these wholes can be called a "holarchy."

  2. Extended Holism

  a. Universe Holism has no extended version because it is already all and everything.

  b. Materialist Holism can be extended by simply listing the elements that are considered a part of the whole. Thus the meaning of "holistic medicine" depends entirely on which items are on the list. It is sufficient for a Materialist holism to have simply two items. Some people, however, consider this a false dualism and affirm that to be an actual whole it has to have three elements.

  c. Logical Holism can be extended by communication and control. The parts can communicate with the whole and the whole can communicate with the parts. This applies to every level of the holarchy. The control system means that each whole and each part has a purpose that involves a change in the larger whole. The whole has to perceive what is going on in the environment and then based on the purpose decide on an alternative to affect the environment. [This was the meaning of Smuts' holism when he coined the term. He was looking at creating a League of Nations that would be a whole that would then be able to control the member states in order to prevent another world war. He saw the development of larger wholes as the basic movement of evolution.]" (Johannson, 2024)

- The emergence of new properties as entities are aggregated into greater entities in a hierarchy of complexity. As Aristotle is thought to have said, "the whole is more than the sum of its parts". Thus, a holistic entity is one with emergent properties. (Preferred)

The definitions given by Holism SIG, clearly demonstrate the different perspectives that people give to more abstract concepts. These definitions were arrived at after much debate and are clearly influenced by each contributor's experience of a finite subset of circumstances in which holism may apply.

In connection with these definitions, it should be mentioned that not everything is related to everything else because, in a relationship, something must pass from one of the related entities to the other, and this cannot occur faster than the speed of light. Thus, for example, the physical universe beyond what we can see has never passed anything to this planet, including gravity which also travels at the speed of light.

Finally, the control components mentioned in "Extended Logical Holism" apply only to living things and some of their artifacts.

L. Holons

Alternative definitions of “Holon” include:

- Any aggregate of more than one entity.
- Arthur Koestler originally described a holon as being any entity that can be recognised as a whole in itself, and which constitutes part of a larger whole (Koestler, 1967). However, for the purpose of this framework, a holon is also a meaningful physical entity with emergent properties that is the aggregate of a collection of other holons. (Preferred)

M. Systems

Alternative definitions of “System” include:

- Anything with inputs, processes, and outputs that persists for a length of time. The difficulty here is one of specifying the length of time that separates what is from what is not a system.
- Any physical entity with inputs, outputs, processes, and emergent properties irrespective of its lifespan. (Preferred)

Thus, a system is a holon and a holon is a system. This is because both holons and systems are physical in nature, can be aggregated and disaggregated, and display emergent properties. They are also meaningful entities, i.e., entities with a structure or pattern that recurs elsewhere. Different terms are used because the same concept has been approached from two different perspectives. In the case of a system, we say that it comprises sub-systems. This is a top-down perspective. In the case of a holon, we say that it is part of a larger entity. This is a bottom-up perspective. In fact, systems are a part of greater systems and also comprise lesser systems; holons are a part of greater holons and also comprise lesser holons.

Although the author is an advocate of systems theory, he uses the term holon in the social context to avoid the colouration attached to the word “system” there. However, as this paper discusses systems theory, the term “system” will be used, rather than “holon” from this point forward.

N. States and changes of state

A state is the set of characteristics that apply to an entity. If that set of characteristics changes for any reason, this is known as a change of state. For example, when two entities are related, they are in a different state than when they are not.

O. Static and dynamic structure

Structure refers to patterns in the way that the component parts of an entity are related. These give the entity the features that we recognise. However, meaningful entities can have a static structure, unchanging in time, or a dynamic one.

Static structure relies on stability. Stability, in turn, relies on there being no change in the characteristics of the entity. For example, this may be the way that an entity’s parts are arranged being in static balance with the forces acting upon them.

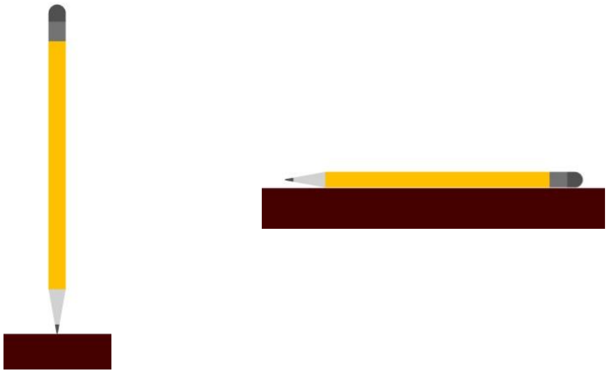


Figure 4. Stability and instability.

A gravitational force acts on this pencil and the pencil's orientation relative to that force determines its stability.

Examples of entities with a static structure are crystals and buildings. However, static structure is only static relative to the human observer. In practice, everything decays with time but, in many cases, this is too slow for us to notice. Some atoms, for example, persist for billions of years. Nevertheless, they were originally assembled from sub-atomic particles and may ultimately return to them. So, static structures are states of organisation that persist from a human perspective.

Entities with static structure are more likely to recur, more likely to be recognised, and more likely to be meaningful to us than ones that are less complex but apparently randomly structured.

Entities that do not have a static structure are, by definition, in a state of change. Unless there is dynamic structure to that change, then we are unable to recognise recurrences. If an entity has dynamic structure, then the change taking place within it is not random, as would be the case with a decaying building. Rather, it is ordered, occurring for example in cycles. For example, a statue of a horse always occupies the same region of space irrespective of time, and so, has static structure. On the other hand, a living horse is dynamic, taking different shapes and occupying different regions of space at different times. However, the shapes that it takes when for example galloping occur in cycles.

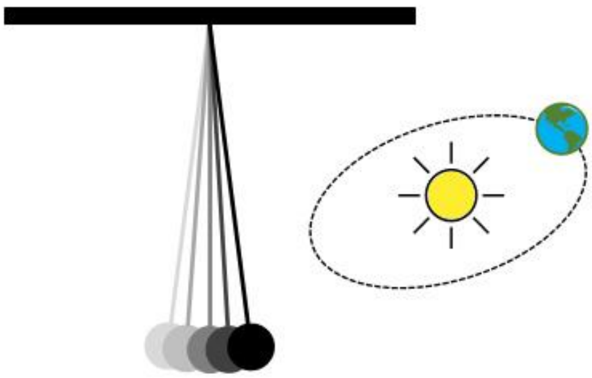


Figure 5. Examples of dynamic structure.

The recurrence of entities with dynamic structure is more difficult to recognise. This is because the mental resources needed to remember a dynamic structure are much greater than those for a static one. The longer the cycle, the more the resources needed, and the less likely we are to recognise recurrences.

P. Causality

Causality is almost ubiquitous and describes the flow of matter and energy in the universe. Matter, as Einstein pointed out, is organised energy. Thus, causality, describes the general energy flux in the universe.

The exception is quantum entanglement, which probably employs some other, yet unknown, mechanism. Entangled particles exhibit unusual behaviour. When a property of one is altered the same alteration occurs, apparently spontaneously, in the other. Initially, the two particles must be closely related, but the same effect occurs instantaneously over a distance when they are separated. This suggests that causality itself is, in part at least, an emergent property. However, because it is almost ubiquitous, we expect it to be entirely so. It is no surprise therefore that Einstein doubted the existence of the entanglement of particles, famously referring to it as “spooky action at a distance”.

Unfortunately, in the English language the term “cause” can refer to an aggregate entity or set, for example “*war* is a cause of poverty”, or it can refer to a member of a collection, for example “*the war* is a cause of poverty”. The same is true of the terms “effect” and “causal relationship”. To distinguish between the two and to avoid any confusion, all references to a member of a collection will be described as an “instance of…”. Thus, several “instances of the cause” aggregate to form “the cause”; several “instances of the effect” aggregate to form “the effect”; and several “instances of the causal relationship” aggregate to form “the causal relationship”.

The instances that are causally related to one another are determined by the geometry of space-time. For there to be an instance of a causal relationship, an instance of a cause must begin before an instance of its effect, and the two must share a region of space-time. An instance of a cause must be an entire entity for so long as it exists. However, an instance of an effect can be an entire entity, or it can be a change in its state. Such a change in state may be the beginning of the entity, its end, or a change in its characteristics. Any characteristic so altered may be a variable one that can be quantified, such as the entity’s mass, and thus, amenable to mathematical representation. Alternatively, it may be one which cannot be quantified, such as the entity’s existence. This is more amenable to linguistic or logical representation.

The Scottish philosopher, David Hume, observed that an instance of a cause must occur before its instance of effect and that the two must be contiguous in space (Hume, 1748). Thus, a causal relationship is recognised when instances of an entity of one type and those of another regularly occur in spatio-temporal proximity.

The impossibility of causality over a distance, together with the sequence of cause and effect, suggest that causality involves something being transferred from the former to the latter. For example, if there must be somewhere for an instance of an effect to take place, the instance of the cause may provide this, for example, a factory provides a space in which to assemble cars. In this example, the cause is passing space to the effect. However, in most cases the instance of the cause passes matter, raw energy, or information to its effect.

Relationships in general can be static, that is, unchanging with time, or dynamic. Physical objects, for example, can be treated as static, reflexive relationships. Causality, on the other hand, is dynamic. Instances of cause and effect are events. This is because there is a time delay between the two. Something is passed from the instance of the cause to its effect and changes take place in the latter. Both take time.

Causes are described as being necessary or sufficient for their effect. For an effect to take place it requires certain inputs. If a cause is sufficient for an effect, then it provides all the necessary inputs. Thus, an effect always occurs in the presence of a sufficient cause. However, the same effect may result from any one of several different sufficient causes. On the other hand, if a cause is necessary for an effect, then it is the only source of some of the inputs needed by the effect. Thus, an effect cannot occur in the absence of a necessary cause.

Figure 6. Sufficient cause.

This is an example of an effect being caused to begin. The effect always occurs in the presence of a sufficient cause. However, it may also occur in the presence of other sufficient causes.

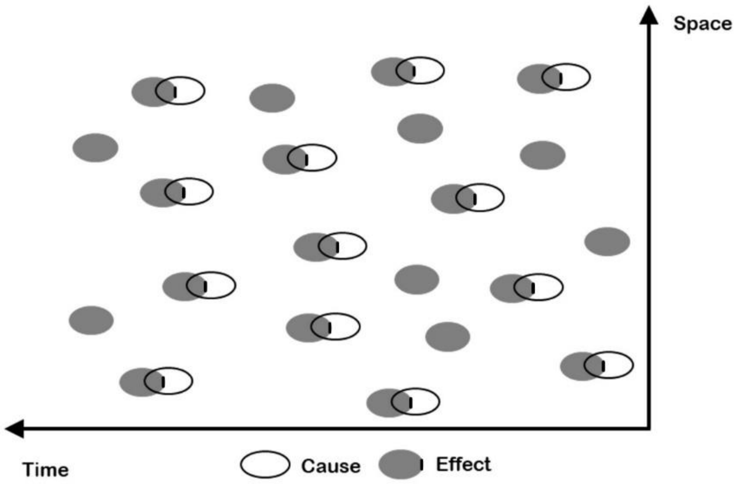
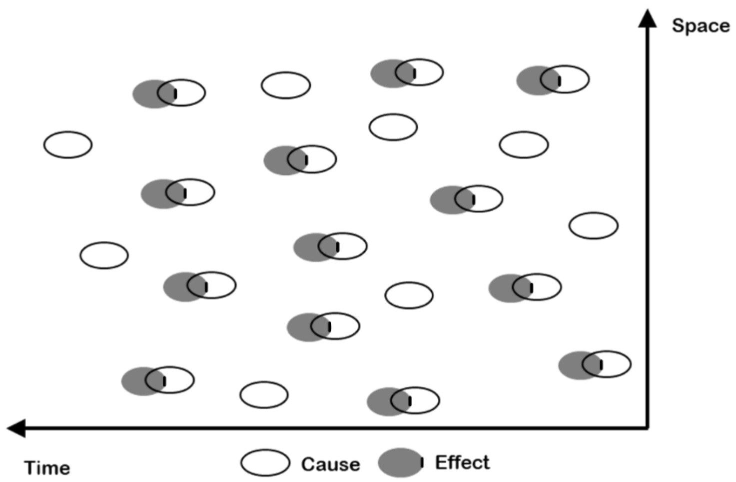


Figure 7. Necessary cause.

This is an example of an effect being caused to begin. The effect cannot occur in the absence of a necessary cause. However, the effect does not always occur in its presence.



It is usually the case that an effect needs several causes to provide all its inputs. Thus, causality is often more complex than a single cause leading to a single effect. The American epidemiologist, Kenneth Rothman, noted that several recognised and named causes may be *necessary* for the effect (Rothman, 1976). However, it is only their un-named and unrecognised conjunction that is *sufficient* for it to occur. He referred to this as the “sufficient component cause model”. For example, factory space, assembly instructions, parts, electricity, people, and machinery are all needed to manufacture cars, but only together are they sufficient.

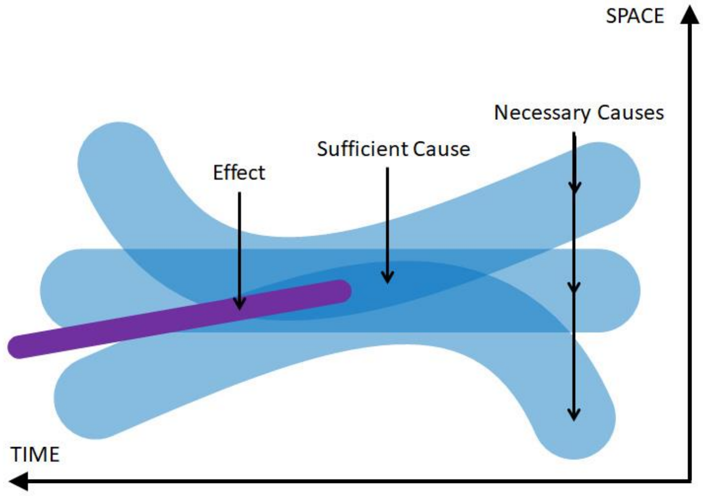


Figure 8. Several necessary causes combining to form a sufficient cause.

Note that, whilst the necessary causes may be meaningful, the sufficient cause may not.

Something that is often overlooked in causality is the existence of inhibitors. That is, those things that prevent an effect. Again, certain inhibitors may be necessary to prevent an effect, but only together are they sufficient to prevent it. The concept of inhibitors is of importance when it comes to the discussion of living entities.

Q. Systems and causality

There are several striking similarities between systems theory and causality:

- Systems are recursive in the same way as causes and effects, i.e., they comprise component systems and are part of greater systems. The same is true of causes and effects. In fact, causes and effects can be broken down as far as fundamental particle level in the same way as systems.
- The same linguistic structure is used in both causality and systems theory. Compare the following, for example: "A cause results in an effect" and "an instance of a cause results in an instance of an effect"; "Industry produces cars" and "a factory produces a car".
- Systems can require several necessary inputs that only together are sufficient for them to function. An effect can require several necessary causes that only together are sufficient for the effect to occur.
- Systems can have several outputs and causes can have several effects.
- There can be complex interactions between multiple systems and the same is true for causes and effects.
- Systems can be collected into types, each instance of which has the same outputs or requires the same inputs. The same is true for instances of a cause or an effect.
- What is transferred between systems or between a cause and its effect is space, matter, energy, or information.

The implication is of course that the normal laws of causality apply to relationships between systems and causality must therefore play a very significant part in any General System Theory. Such a system theory would enhance the theory of causality by explaining its operation.

A system is therefore more than a physical entity. It is another way of looking at causality. This is demonstrated by the diagram below (Korn, 2022). The processes in a system produce outputs, which is an event. They also consume inputs, which is another event. If one system produces an output that is consumed by another, then we have two interlocking events which share a common feature, their output or input. This output or input is, of course, what is transferred from one system to the other. So, one system, comprising inputs, processes, and outputs, can be regarded as an instance of a cause, and the other system, comprising the same, as its effect.

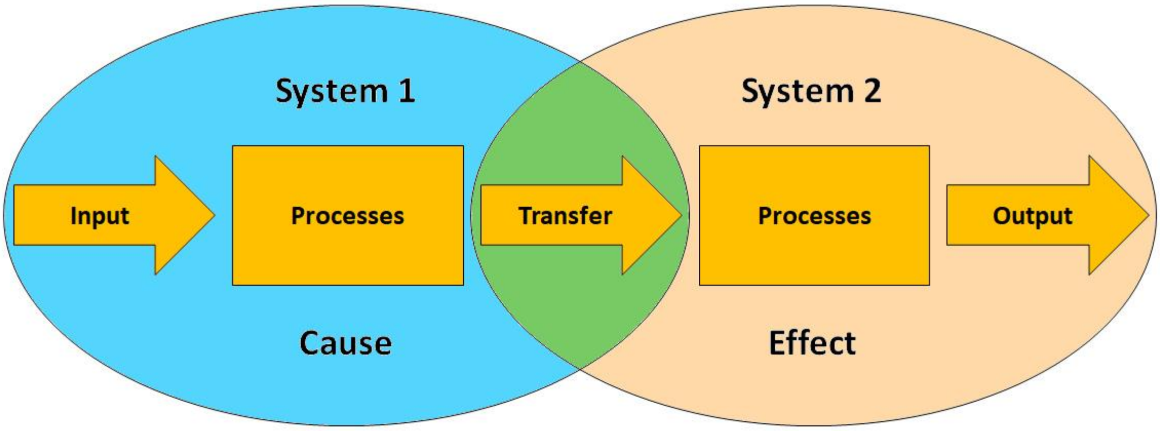


Figure 9. Systems can be regarded as causes and effects.

The output from one system is the input to another and this is equivalent to a transfer of space, matter, energy or information between a cause and its effect.

Causality does not apply to an individual system, of course. However, if a system is not treated as a single entity but rather as a collection of interacting subsystems then causality can be applied to those interactions.

R. Causal patterns or structures

Like other entities, causality can be structured and meaningful, or apparently random. Again, what is meaningful relies on our ability to recognise structure and its recurrence. Causal patterns are formed of several, often many, causal relationships. Unfortunately, the recognition of these patterns is far more difficult than the recognition of a single relationship. Relatively few have been recognised to date, therefore.

Harvard Graduate School of Education lists the following (Grotzer, 2010).

- Linear causality. This is causality at its simplest, comprising a single sufficient cause, and a single effect.
- Domino causality. A chain of linear causality leading to the sequential unfolding of events over time.
- Cyclic causality. A chain of causality in which the types of entity alternate, for example, chickens and eggs.
- Spiralling causality. This is also known as a feedback loop or, more accurately, spiral. It is a circular chain of causality in which changes in the state of one entity can be a consequence of changes that the entity has previously wrought in another. This may have been directly or via a causal chain. The classic example is a microphone placed in front of a loudspeaker. The resulting sound is a consequence of positive feedback. Negative feedback is also possible. In this case a variable feature of an entity is reduced to, and

maintained at, zero. Finally, regulating feedback holds the variable characteristic of an entity at a particular value. For example, a governor regulates the speed of a steam engine.

- Relational Causality. The relationship between two entities acts as a cause. For example, if one entity has a mass greater than the other, then the effect occurs but not otherwise.
- Mutual causality. In mutual causality two entities affect one another, for example a flea causes an effect in a dog and vice versa.

To this list, I would add the following.

- Cascading causality. In this structure, the components in a causal chain also affect an entity outside of the chain, steadily amplifying or reducing a variable characteristic. For example, the familiar human practice of “digging oneself into a hole”. Like feedback, cascading causality can be positive or negative.

Regarding spiralling causality, a positive feedback loop must have inputs because variable characteristics in its components are increasing. For example, the microphone and loudspeaker referred to above require an input of energy via the amplifier. Similarly, a negative feedback loop must have outputs because variable characteristics in its components are decreasing.

The third form of feedback loop, the regulating one, provides stability. This is because variable characteristics in its components remain stable or oscillate around a mean. This suggests that stable self-maintaining systems must also contain feedback of this nature. An example is the management or control component that we see in organisations. This component receives information and outputs instructions to stabilise the organisation. In non-living things regulating feedback would, of course, rely on the transfer of something other than information.

S. Function & Purpose

The outputs of a system can be regarded as its function. However, because these outputs are inputs for other systems, i.e., effects, these effects can also be regarded as the system’s function. The purpose of a non-living entity is the same as its function. However, a living entity with agency can regard its purpose as being what it would like its function to be.

T. Physical laws & theories

A physical law or theory is a statement of a causal relationship in which entities of one type, the cause, always result in changes to entities of another type, the effect. Often, variations in a characteristic of the cause result in variations in a characteristic of the effect. If so, then the law or theory can be expressed mathematically. However, this is not always the case and mathematics cannot always be applied.

Physical laws and theories are a subset of all relationships, and the same principles apply to them.

U. Needs, Satisfiers and Contra-satisfiers

We use different language when referring to living entities and their artifacts than when referring to other systems. The needs of a living entity or artifact are the equivalent of its processes. If those needs are not satisfied the processes fail to operate, i.e., produce their outputs. For example, if we lack oxygen we die. The same is true of some of our artifacts. If a factory lacks electricity it ceases to produce its products. The inputs to living entities and their artifacts can be satisfiers or contra-satisfiers. A satisfier is an input that increases the ability of the processes to produce their outputs. It increases the level of satisfaction of the system’s needs. A contra-satisfier is an input that decreases the ability of the processes to produce their outputs. It decreases the level of satisfaction of the system’s needs. This input and the system that produces it is an inhibitor.

Although they apply mainly to living things and their artifacts, the terms need, satisfier, and contra-satisfier can be used more generally.

V. Recursion.

Space-time is a continuum. Every region of space-time comprises yet smaller regions. Every region also shares smaller regions with other regions. So, because every entity occupies a region of space-time, every entity can be broken down, or disaggregated, into parts. Those parts are shared with other entities, albeit not necessarily with meaningful ones. This recursion begins with the universe in its entirety and continues downwards in scale to the sub-atomic level.

The reverse is also true. Every region can form a part of several greater regions, every entity can form a part of several greater entities, and several entities can be aggregated to form a greater one. This begins at the sub-atomic level and continues upwards in scale to the entire universe.

Because relationships, including events and causality, are two entities in conjunction together with whatever passes between them, they are recursive in the same way. Every relationship, cause, or effect comprises several lesser ones and is a part of greater ones.

In practice, however, we disaggregate entities into meaningful parts, known as components. For example, we would disaggregate a wall into its bricks, and not into random sections of wall or parts of bricks. Thus, we impose discreteness on the continuum in order to comprehend it.

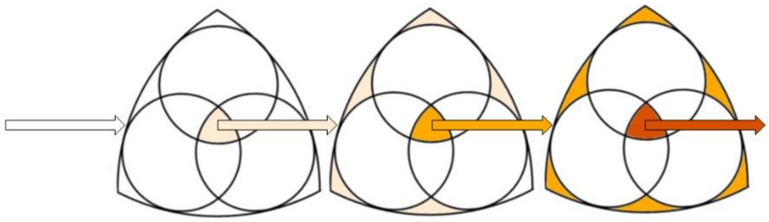


Figure 10. Diagrammatic representation of a continuum.

Every entity or triangle comprises parts or circles. The parts or circles intersect to form other entities or triangles, and so on ad infinitum. Note that the parts are also entities and the entities also parts. They are shown in threes and in these shapes for ease of explanation. In practice however, they can be of any number or shape.

W. Lower limit to recursion.

There may be a lower limit to recursion, however. The lowest level of recursion, known to us at present, comprises the fundamental sub-atomic particles and the four fundamental forces of physics. The latter are the strong nuclear force, the weak nuclear force, the electro-magnetic force, and gravity. For the present, at least, these particles appear not to comprise lesser particles, and the forces not to comprise lesser forces. Thus, the four fundamental forces of physics are the fundamental components of causality.

Apart from gravity, the fundamental forces have been shown to involve transfers of energy using "exchange particles". In the strong nuclear force, the exchange particles are gluons; in the weak nuclear force, they are bosons; and in the electromagnetic force, they are virtual photons. The latter are temporary fluctuations in energy at a point in space. These transfers occur over a period determined by the speed of light and the transfer distance. The fourth fundamental force, gravity, is believed by some physicists also to involve an exchange of particles, i.e., gravitons. However, gravitons are hypothetical, have never been detected, and the equipment needed to do so is beyond our ability to manufacture at present.

X. Granularity

Granularity describes the disaggregation of a system into component systems ones. The first level of granularity comprises the greatest systems that together fully comprise the entity. For example, the first level for a jellyfish would be its organs. The second level comprises the next greatest systems that do the same, its cells, the third level its molecules and so on.

As the level of granularity increases, the number of components systems of an entity increases, and their complexity decreases. Least granularity comprises just two parts; greatest granularity typically comprises all the sub-atomic particles of the entity. This is approximately 7x10^28 for a human being.

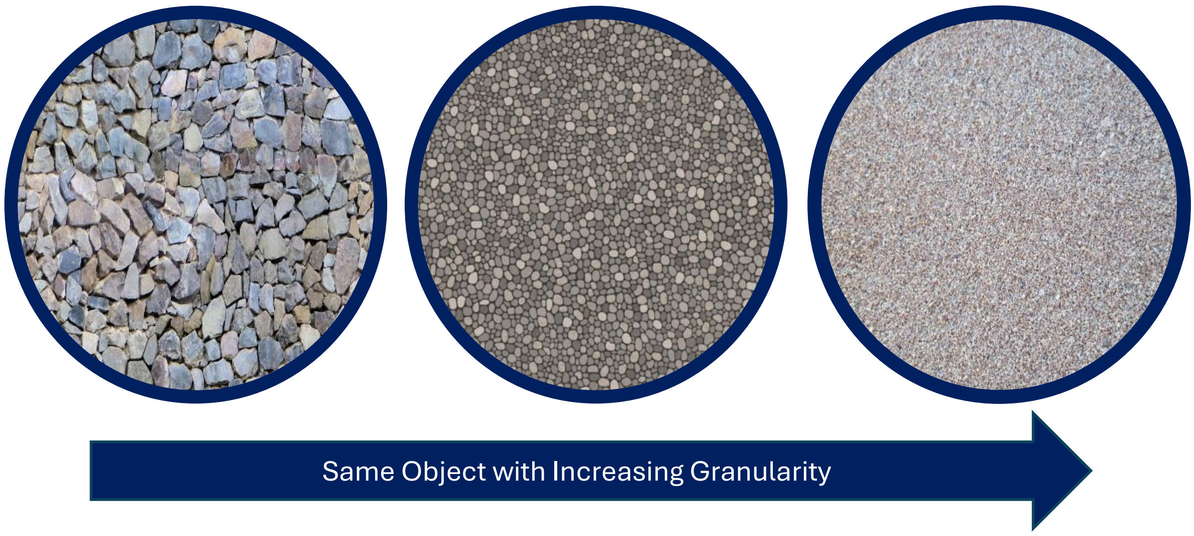


Figure 11. Granularity.

Y. Complexity

Alternative definitions of “Complexity” include:

- The number of component systems in an entity.
- The number of fundamental sub-atomic particles in an entity. For the present, at least, we can regard fundamental particles as those identified in the Standard Model of physics. (Preferred)

The latter is preferred because it is objective and applies at all scales, whilst the former is subjective and relative to the systems under consideration.

Every physical entity, whether meaningful or not, can be regarded as lying on a scale of complexity, from a single sub-atomic particle to the entire universe. The term “complexity” does not imply that the entity is either ordered or disordered. Rather, it merely refers to the number of sub-atomic particles that it comprises.

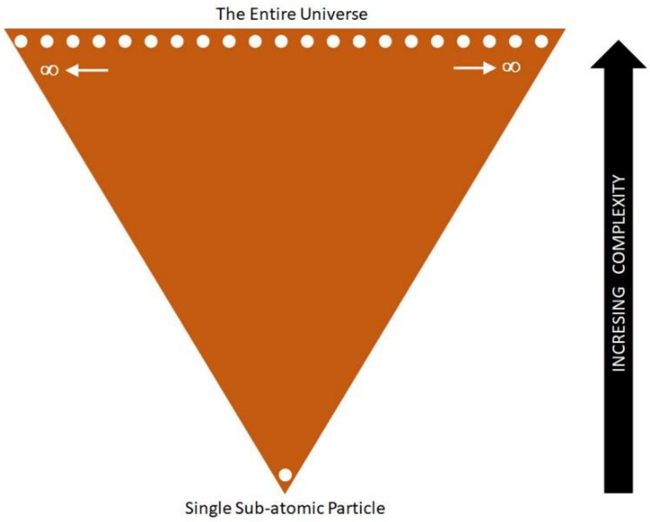


Figure 12. The complexity of entities.

Each white dot represents a sub-atomic particle. The complexity of an entity lies on a scale from a single sub-atomic particle to all sub-atomic particles in the universe.

Ultimately, every physical entity, its properties, and its relationships with other entities are the consequence of sub-atomic particles and their interactions. The more complex an entity, the greater the number of particles and interactions. The same is true of relationships. The complexity of a relationship is the sum of the complexity of the two related entities.

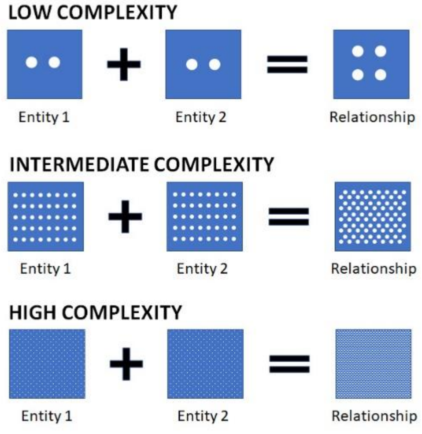


Figure 13. The Complexity of Relationships.

Each white dot represents a sub-atomic particle. Because the relationship comprises the two related entities in conjunction together with anything transferred between them, its complexity grows with the complexity of the related entities. Relationships include causal ones and physical laws.

Alternative definitions of a “Hierarchy of Complexity” include:

- Something comprising levels, each of which is a system.
- Something comprising levels, each of which is a number of fundamental particles. (Preferred)

The level of complexity of a system increases and decreases during its life. This is due to ongoing inputs and outputs. Ultimately, most systems disappear entirely, i.e., their level of complexity becomes zero. Some can self-maintain for a time within a range of complexity. Others can disappear entirely after a very short life.

We form collections based on the similarities that we observe between entities. This is a human cognitive act. The more fundamental particles an entity comprises, the more variability there is between entities in the same collection, and we are limited in the amount of complexity that we can comprehend. So, to address this variability we create prototypes, i.e., mental images of a typical member of the collection that have only the characteristics we have used to define that collection, and none of the variability.

Interactions can take place and relationships can exist between systems that occupy different levels of complexity.

As a rule, as entities become more complex so too do their potential characteristics. Thus, characteristics emerge with the increasing complexity of entities.

As a rule, also, as entities become more complex so too do their potential relationships, i.e., what they receive from and pass to other entities. Thus, types of relationship emerge with the increasing complexity of entities.

Z. Isomorphisms

The term "isomorphism" literally means equal in form or shape. In system theory the term is used to describe two systems that have components with the same pattern of interactions. Because interactions between systems are causal, isomorphisms are systems that have the same causal patterns within them.

Two isomorphic entities do not necessarily have identical components. Nor do those components necessarily have the same arrangement in space. Furthermore, what is transferred between those components is not necessarily the same. Isomorphic entities do however have the same number of components and the same pattern of causal relationships between them.

For example, a positive feedback loop may have as its components firstly an electrical system, i.e., a microphone, an amplifier, and a loudspeaker, and secondly a sound transmission system, i.e., air. What is transferred from one to the other is raw energy. An increase in electrical energy causes an increase in sound energy that, in turn, causes an increase in electrical energy. The fruit ripening process is also a positive feedback loop whose components are firstly the ripening system, a chemical system, and secondly air, i.e., a gas transmission system. As a fruit ripens it produces ethylene gas which causes adjacent fruits to begin to ripen and also produce the same gas. What is transferred are chemicals. An increase in ripening chemicals causes an increase in ethylene gas that, in turn, causes an increase in ripening chemicals.

This isomorphism involves two sets of entirely different systems and different transfers between those systems. It is however explained by a common causal structure, the positive feedback loop. However, it can be difficult to select the appropriate level of granularity and an unfamiliar one has been used to reveal this isomorphism. Furthermore, it can be challenging to identify what is passed from one system to another in a causal relationship.

Nevertheless, isomorphisms can be used to improve our understanding of causal structures, which at present is very basic and limited. It is not necessary to use mathematics to identify isomorphisms. Rather, identification of the systems involved, and a comparison of the pattern of causal relationships between them can achieve the same result.

AA. The emergence of properties and physical laws

As the complexity of entities increases, properties that their components do not have can emerge. Novel properties and thus systems do not emerge at all levels of complexity, however.

They only emerge when there are a sufficient number of fundamental particles in an entity, and they are related in a particular way.

This is reflected in human cognition and language. We only give names to things that are structured and that we recognise as recurring, for example, "cells" and "organs". We do not give names to entities of intermediate complexity, just descriptions such as "a clump of cells".

New properties emerge in discrete steps at different levels of complexity. This is because increasing complexity permits a larger number of fundamental particles to be related in a more complex way.

The static or dynamic stability of structures plays a significant part in emergence. An emergent property may, for example, be the consequence of a stabilising feedback loop between the entity's components. To create such a loop a minimum number of components may be required. So, stable structure emerges in discrete steps. Between the levels of complexity at which stable structure emerges, entities have an unstable static structure that, by definition, is in a state of change. For example, a human cell has a structure that we recognise as recurring elsewhere. However, as complexity increases, cells join apparently randomly and the way that they do so changes with time. It is only when we reach the level of an organ, e.g., the heart, that stable structure appears again. Thus, as we ascend the scale of complexity, we have order, then disorder, then order again, and so on.

New properties can be physical laws. This is because physical laws are causal relationships between systems. These causal relationships are determined by what is transferred from one system to the other and what is transferred is a part of the source entity. So, as the complexity of the source entity increases what is transferred can also increase in complexity. Thus, new physical laws also emerge in discrete steps at different levels of complexity.

Looking at the emergence of physical laws in another way, as entities become more complex so too do their potential characteristics. One characteristic of an entity is its outputs. So, as entities become more complex so too do their potential outputs.

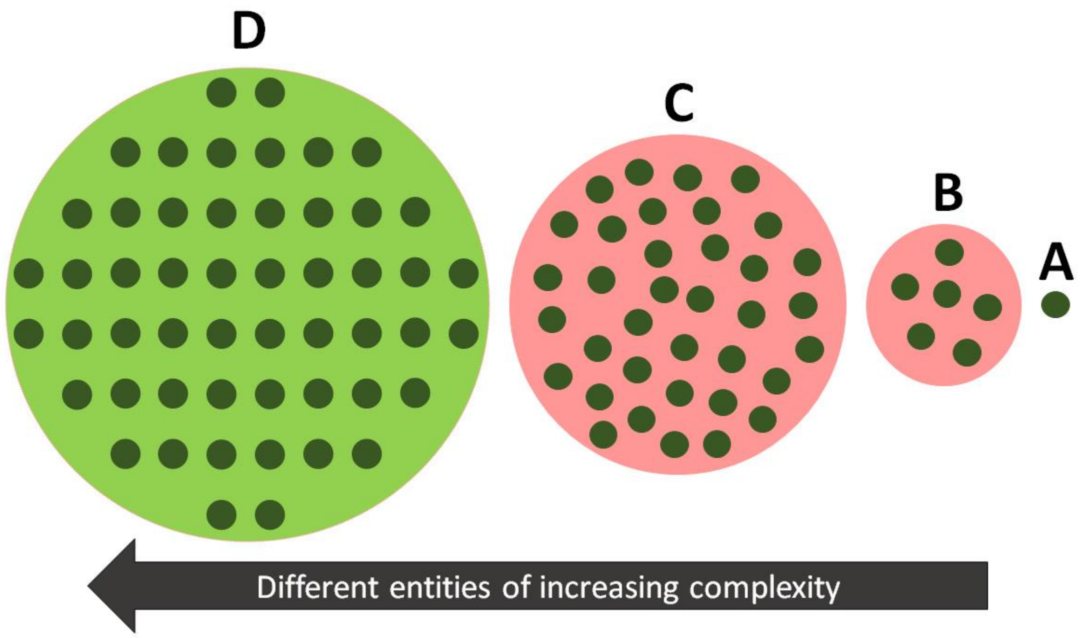


Figure 14. Increasingly complex systems.

Green circles indicate systems. Red circles indicate other entities. Starting from the right, A is a single system. B is a simple combination, with no recognisable structure, of systems. C is a more complex combination, with no recognisable structure, of systems. D is a system with a recognisable structure and many component systems from in which a new property emerges. D can, therefore replace A, and growth in complexity can continue with D as the component.

However, types of system do not all emerge at the same level of complexity. Rather they emerge within a range. Molecules, for example, can vary in complexity from a simple hydrogen molecule to DNA, and the number of sub-atomic particles in each differs substantially.

This is reflected in granularity. Although a system emerges at a particular level of complexity, not all the component systems that form it emerge at a common level. Rather they emerge over a range of levels. So, for example, the first level of granularity occurs at the level of complexity where the most complex component system emerges. Fortunately, such ranges are relatively narrow in comparison with the total range of complexity.

BB. Chaos and the limits to our ability to comprehend complexity.

Our reason for wishing to understand a system is to predict its behaviour, to grasp opportunities, to avoid threats, and thus, satisfy our needs. However, three factors conspire against this, meaning that we can only model complex systems a very short distance into the future before errors become significant.

Firstly, it is in our nature to understand systems in terms of their component systems and the interactions between them. Because systems do not emerge at all levels of complexity, as the level of complexity increases, the number of interactions between systems that have emerged at a lower level also increases. There is a limit to the number of interactions that we can understand. As this number increases with complexity, our threshold of comprehension is eventually overwhelmed, and the situation appears chaotic. When recurring patterns can be identified this is usually because a novel property has emerged and a new system can be identified.

Secondly, in very complex systems, chaos theory applies. The smallest error in any parameter can quickly become magnified by the number of interactions. Thus, outcomes with and without the error diverge, becoming increasingly dissimilar with time.

Thirdly, random events can affect outcomes. For example, the radioactive decay of atoms and the appearance of “virtual particles” are thought to be entirely random. These events can have a similar effect to that of a small error.

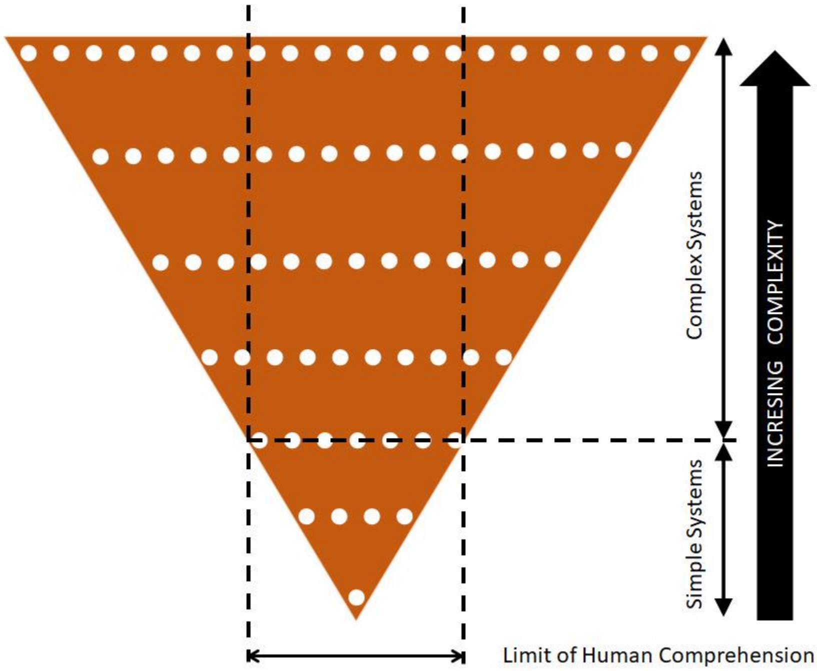


Figure 15. Simple and complex systems.

CC. Simplification.

When faced with chaos, our natural inclination is to simplify the interactions between its components, bring them back within the limits of our mental capacity, and, thus, attempt to reinstate a degree of predictability. Typically, simplification involves placing entities into broader categories using fewer shared characteristics. For example, we might use the category “forms of transport” rather than the category “cars”. We may also select variable characteristics to which a value can be given, such as weight, and create categories based on value ranges, for example “light”, “medium” and “heavy”. In this way, the number of entity types is reduced, and so too are the number of relationships between them.

However, error-free simplification is only possible at a level of complexity where new properties emerge. If complexity becomes too great for us before that level is reached, then any simplification will introduce error. Thus, there are gaps between levels of emergence in which the relationships between entities cannot be accurately understood. Furthermore, simplification only helps us to deal with increasing complexity until our threshold of comprehension is reached once more. If this occurs at a level lower than the next level of emergence, then further simplification will be needed. With each simplification comes error. So, if we wish to avoid an unacceptably large accumulation of error, then we cannot rely on pure theory, and must carry out experimental observation. For example, in attempting to understand society, simplification may lead to ethnic type-casting. Becoming acquainted with people from other ethnic communities would counter this.

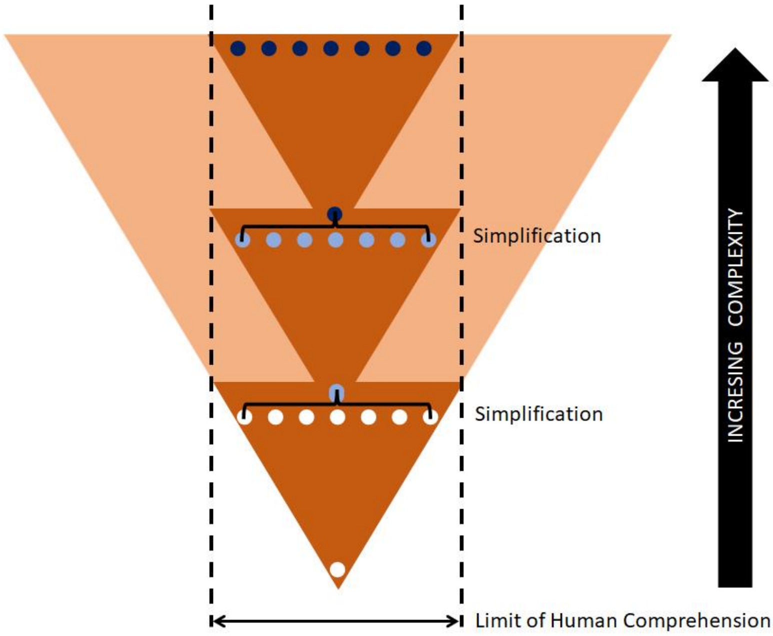


Figure 16. Progressive simplification.

We simplify systems if our threshold of comprehension is reached before the next level of emergence. With each simplification the threshold of comprehension can be reached once more, and we must simplify yet further. However, with each simplification, information is lost and error introduced.

Because we simplify our fields of knowledge using emergent properties and their associated systems, a type of interaction that has emerged at a lower level of complexity may be entirely subsumed within the systems that we employ. For example, it may be possible to explain human society using fundamental particles, but the number of particles involved is far beyond our ability to do so. Rather, we attempt to explain society in terms of the interactions between groups of people.

DD. Hierarchies of disciplines.

A discipline is a field of knowledge with its own distinct systems and laws governing the relationships between them.

As complexity increases, new disciplines arise when entities with novel properties emerge. These then form the systems employed in the discipline. The relationships between them can be the discipline's laws or theories. As complexity increases, so too does the number of systems and the relationships between them. The discipline attempts to explain these until a level of complexity is reached at which systems with new properties emerge once more. A new discipline is then founded.

The systems employed in each discipline are stable structures of relationships between component systems. In turn, those components are formed in the same way, but at a lower level of complexity. For example, organs derive their stable structure from relationships between cells. Those cells, in turn, derive their stable structure from relationships between molecules, and so on. However, a discipline considers only its own systems and not their sub-systems or sub-sub-systems.

Because they are dependent on a minimum level of complexity, the laws and theories that emerge for a discipline cannot apply to disciplines at lower levels of complexity. This leads to a hierarchy of disciplines, each with its own distinct systems, relationships, and theories, each dependant on the speciality below, and each lying on a path of increasing complexity.

The path of increasing complexity shown in the diagram below is relevant to human social systems. Each level of emergence, results in a new discipline. In this diagram, social science includes psychology, social psychology, sociology, economics, and political science.

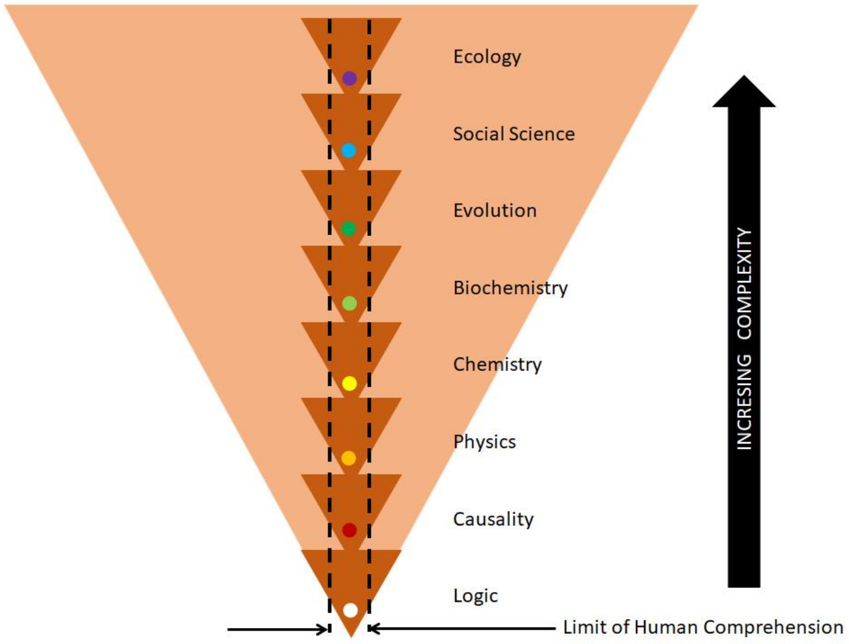


Figure 17. The emergence of disciplines with increasing complexity.

EE. Divergence of paths of increasing complexity.

Because emergent properties rely not only on a minimum number of fundamental particles, but also on the relationships between them, emergence does not follow a single path of increasing complexity but many. For example, stars emerge on one pathway and life on another. Thus, disciplines also emerge on different pathways. These paths diverge, as shown in the diagram below, to form a tree-like structure.

Different laws and theories emerge on each path of increasing complexity. Those that emerge for life, for example, differ from those that emerge for astro-physics. Each discipline on a branch is dependent on those below. That is, the laws or theories at a lower level in the branch also apply at the higher levels. However, the reverse is not true. Laws and theories that have emerged at a higher level do not apply at lower levels. Thus, one would expect disciplines to differ and for isomorphisms between them to be based on properties that have emerged at a lower, common level of complexity.

Paths also combine, and branches of the tree can merge. For example, ecology is a discipline that depends not only on the life sciences but also physical sciences such as geology. If the universe were finite, then all paths would merge when the level of complexity reaches the universe in its entirety. At this point, all laws and theories would interact to form the universe as a whole. However, the universe is probably infinite and, were it not for the limitations imposed on causality by the speed of light, new properties and disciplines would emerge indefinitely.

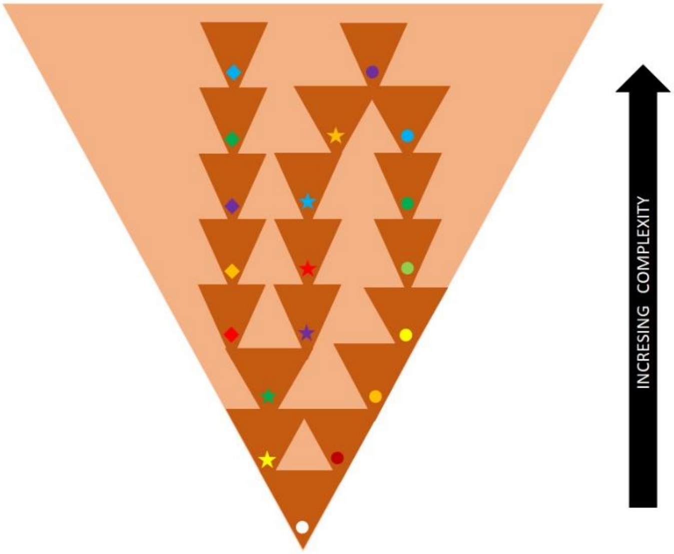


Figure 18. Diverging paths of increasing complexity.

The small brown triangles represent the different disciplines, for example physics or psychology. The coloured symbols represent the systems employed in each discipline.

v) Entropy.

Entropy is a measure of disorganisation in an entity. The concept was first introduced, in 1865, by the German physicist, Rudolf Clausius (Clausius, 1867). Later, the Austrian physicist, Ludwig Boltzmann, described it as a measure of the number of ways in which particles can be arranged in an entity consistent with its large-scale general condition. It has been suggested that, because entropy is a measure of disorder and because information is related to order, that information is the reciprocal of entropy. This is not strictly correct. Nevertheless, entropy plays a significant role in the universe.

The second law of thermodynamics was developed in the 1850's based on the work of Rankine, Clausius and Lord Kelvin. This law applies to closed systems into which energy cannot enter and from which it cannot escape. The law states that, in a closed system, as energy is transformed from one state to another, some is wasted as heat. Importantly, however, the second law also states there is a natural tendency for any isolated system to degenerate from a more ordered, low entropy state to a more disordered, high entropy one.

Based on the assumption that the entire universe is a finite closed system, overall, entropy is thought to be increasing and the universe becoming ever more disorganised. Thus, we cannot expect everything to be a structured and recognisable entity. Locally, however, entropy can decrease, and organisation increase. Life is one example of this, but local decreases in entropy are not its sole preserve.

In 1944, the Austrian physicist, Erwin Schrödinger, raised an apparent paradox in his book "What is Life" (Schrödinger, 1992). This was the tendency for living systems to become more organized as time progresses. This appears to contradict the second law of thermodynamics. There is no real paradox, however. All systems are, by definition, open systems and so living beings are not closed systems. they use free energy from the sun. In striving to maintain their integrity they increase entropy in their surroundings, and, in total, net decay still occurs. Nevertheless, this anti-entropic behaviour is a distinctive feature of life.

FF. The nature of information.

Alternative definitions of "Information" describe it as:

- Something that is metaphysical.
- Something that is inherent in the structure of entities in space-time whether they be matter, energy or both. (Preferred)

We tend to regard information as something intangible, as being in some way separate and distinct from matter and energy. But this is not so. Information is not merely conveyed by matter and energy; it is integral to it in the form of order and structure. Thus, for example, information is held in the shape of letters written on a piece of paper, in the modulation of sound waves, radio, or electrical signals, in the way that neurons are connected in the brain, in patterns of magnetisation on a hard disk, and so on. Thus, information has physical existence in the same way as all other entities in the universe.

Information exists at source, i.e., within the entity that it describes. This information at source can be replicated but in doing so it must also be translated. Were it merely to be replicated then there would be two identical entities occupying the same region of space-time, which is clearly impossible. Nevertheless, for an entity to be meaningful, its information at source must recur elsewhere.

An entity's components do, of course, have their own information content or descriptions. These do recur within the entity, but they are descriptions of the components rather than of the entity itself. So, they are not included in the entity's information at source. Thus, information at source is the structure inherent first level of granularity, i.e., in the least granularity that displays that structure just once.

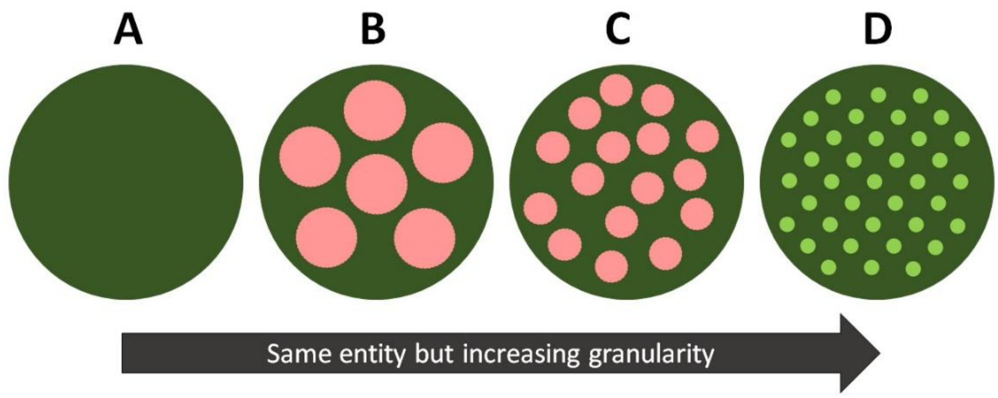


Figure 19. The same entity with increasing granularity.

Green circles are systems. Red circles are not. A represents the system. B is the system disaggregated into meaningless parts. So too is C. D is the system broken down into its largest component systems. The components shown in D and the relationships between them are therefore the information at source held by the entity.

Imagine a typical event, for example a hammer striking a nail. Events comprise one entity interacting with another. The world is full of things that strike one another, and so, just two components, the hammer, nail, and the relationship between them, are sufficient to meaningfully describe the event. This then becomes the information inherent in the event. However, if it is broken down further into, say, random pieces of iron, some of which are part of the hammer, some of which are part of the nail, then no recognisable pattern of relationships exists between them. This is because the way in which these relationships are organised exists nowhere else. These components are therefore disordered and provide no information about the event.

The event can be broken down yet further into atoms. These atoms do interact in an ordered way to form the molecules of the hammer and nail. However, rather than providing information about the event, they provide information about molecules. Whilst it is true that this information is repeated elsewhere, in an asteroid for example, it is also true that it is repeated many times within both the hammer and the nail. Thus, it does not constitute information about the event.

For an entity to be recognised, its information at source must be translated and replicated in the medium of the recognising agent. Once information at source is replicated and translated, the result may be replicable without translation. For example, a photograph or verbal description of a cat can be reproduced many times, but these copies may not occupy the same region of space-time.

The original entity may transmit information to our eyes. We then perceive it as a mental image, remember it, give it a name, and speak that name to someone else. At each stage, translation and transmission takes place. Also, at each stage information lies in the structure of a physical thing. These structures are related to one another by a one-to-one relationship that we call translation. So, a configuration of firing neurons, or a sound vibration, or a pattern of electrical pulses may all, despite their differences, represent a “dog”.

This process of replication and translation is only carried out by living entities and some of their artifacts. There is no evidence of it occurring elsewhere. It is an evolved ability that enables us to avoid threats and seize opportunities. However, our perception and information processing abilities are limited and flawed. So, in translating and communicating we simplify; we assume; we make mistakes; we reject or modify new information that is not consistent with our existing knowledge; and so on. Thus, information can be false.

Note that entropy is not the reciprocal of information at source. Entropy is understood in physics to be disorder at every level of an entity from the atomic level upwards. It is, therefore, the reciprocal of information at all levels, i.e., of the total information in an entity and in all its parts. It is not the reciprocal of information at just one particular level, as employed in human reasoning.

GG. The properties of information.

The general properties of information are as follows.

- Because information is order inherent in matter and energy, an item of information occupies a region of space-time.
- Information is recursive. Any item of information comprises lesser items and is a part of greater items. Some of these items are meaningful, whilst others are not. Only the former are information.
- The least or atomic component of information at source is a meaningful physical entity. The least or atomic component of translated information is any symbol, e.g., a word, representing a meaningful entity.
- The molecular component of information at source is a relationship between two meaningful entities. The molecular component of translated information is also a relationship between meaningful entities, e.g., a proposition in logic or a sentoid in natural language.
- Information at source comprises meaningful components in a meaningful structure. It is inherent in the least granularity that contains it just once. Information at lower levels of

granularity is excluded. For example, we may name an individual person or film them, and replicate that information, but we do not replicate their cellular structure or thoughts. The matter or energy onto which the name or film is replicated may comprise an entirely different sub-structure, e.g., the cellulose of paper, the neural connections of a brain, or the magnetic particles in a hard disk.

- An important feature of information is that it can be replicated, whilst raw matter and energy cannot. Structure in one place can be copied to another. The term "replication" is used because information is established in the latter place, whilst also being retained in the former.
- Information can be transmitted from place to place causally. This can be via a medium such as a book, or via a chain of micro-causality such as that in electrical cables. In living beings, information is transmitted via DNA or RNA molecules. These media are also known as channels.
- Information at source is, by definition, always true. However, replicated information can be true or false.
- Information is translatable. Structure in one medium can represent, rather than replicate, a different structure in another. Notably, patterns in the physical universe are encoded as patterns in the mind and in language. The author's book, "The Mathematics of Language and Thought" gives a detailed explanation of how physical entities and relationships translate into natural language, symbolic logic, and mathematics (Challoner, 2021).
- Although information is not the reciprocal of entropy, entropy and information are related. The second law of thermodynamics states that, in a closed system, entropy increases with time. Thus, in a closed system, any structure held by matter and energy, for example information, must decrease with time. This includes information at source or in replicated form. So, information, naturally decays unless it exists in an open system and is maintained. Meaning is lost through errors of transmission. Individuals and societies forget.
- According to the American mathematician, Claude Shannon, and the physicist, Warren Weaver, decay in transmission is caused by noise in the channel (Shannon & Weaver, 1949). Noise is anything which can alter information during its transmission. However, this theory neglects the many other ways in which human communication can fail.
- The problem of noise and other factors interfering with communication can be minimised by redundancy. Redundancies can comprise repetition of the same component of information or duplication of the channels through which it is transmitted. They can also comprise recursion, i.e., the same component of information repeated at different scales. Information can also contain irrelevances, i.e., meaningless components which have no influence on the information content of the entity. Thus, when irrelevances or redundancies exist, information can often be condensed without any loss of meaning.

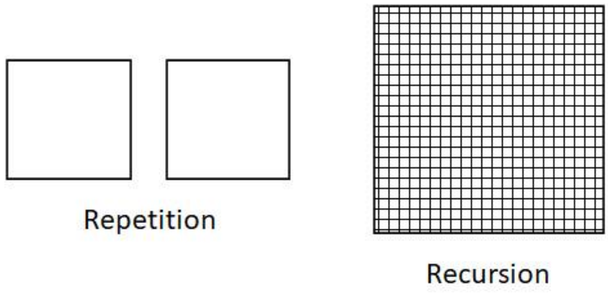


Figure 20. Repetition and recursion.

- The principle of darkness (Cilliers, 1998) states that no system can be known completely by anything less complex. However, this principle assumes that the information content of a system must be replicated in the one that "knows" it, and thus, that the latter must be sufficiently complex to hold it. However, information can often be condensed without loss of meaning. Thus, the information transferred to an entity does not necessarily specify its structure in detail. However, it must provide the rules by which the structure within the entity becomes established. Thus, a modified principle of darkness would state that no system can be known completely by anything insufficiently complex to hold its information in a condensed form. Failing that, the information must be simplified and will, therefore, contain errors.
- Importantly, the transfer of information can provide a basis for the establishment of the relationships needed for a stable structure.

HH. Language.

Natural spoken language has evolved alongside human cognition. This is evidenced by the fact that there is no central language processing part of the brain. Rather, language processing is distributed throughout it. Any processing centre is concerned only with motor functions, i.e., with turning language into speech (Evans, 2014).

The purpose of language is communication. We are a social species, and the aim of communication is, as far as reasonably practicable, to unite our minds and co-ordinate our behaviour. This too is a survival characteristic. To achieve this, language must resonate with how we think and how we understand the world that we inhabit. It must reflect the structure of human cognition. So, natural languages contain "universals". These are features common to every language, and the most notable is the proposition. A proposition comprises two entities and the relationship between them. A simple natural language proposition comprises a subject (entity 1), an object (entity 2), and a verb (relationship). For example, "The apple (entity 1) is (relationship) green (entity 2)". Here "green" is a simplification of the phrase "a green thing". Propositions are fundamental to the way that we reason. They reflect our understanding of the universe, which comprises physical things and the relationships between them. Thus, language, in turn, is a reasonable reflection of the world that we inhabit.

Logic is a formalisation of natural language in which the rules of reasoning are stated clearly, leaving no room for confusion or doubt. Thus, logic demonstrates that reasoning is inherent in natural language and provides further evidence of the close relationship between language and human cognition.

Mathematics on the other hand, although it is a formal language, is a subset of natural language. It contains the same universals. For example, 5 (entity 1) < (relationship) 6 (entity 2). However, it applies only to characteristics that are variable in nature and that can be quantified. For example, the weight of an object.

II. Possible limits to human knowledge.

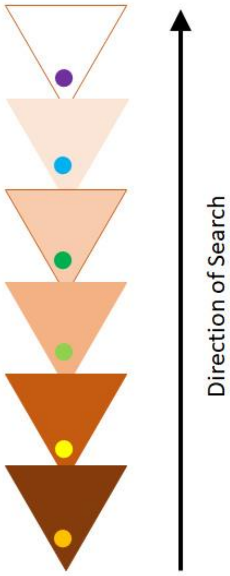


Figure 21. Knowledge at increasing levels of complexity.

The triangles represent disciplines, for example physics. The coloured dots represent the fundamental entities in each discipline, for example molecules in chemistry. The search is in the direction of increasingly complex fundamental entities.

There are difficulties in observing reality at very high levels of complexity. In general, the more ordered the elementary components and relationships within an entity, the greater the likelihood of it recurring and being recognised. However, it is also true that the more complex an entity is, the greater its size, and the greater its size, the less the likelihood that we will be able to perceive it. Furthermore, it is less likely that an entity's structure will recur within a timeframe that allows us to recognise its recurrence. Thus, there may be an upper threshold to complexity beyond which we are unable to perceive recurrence, and thus, recognise and name entities. This includes natural laws and scientific theories.

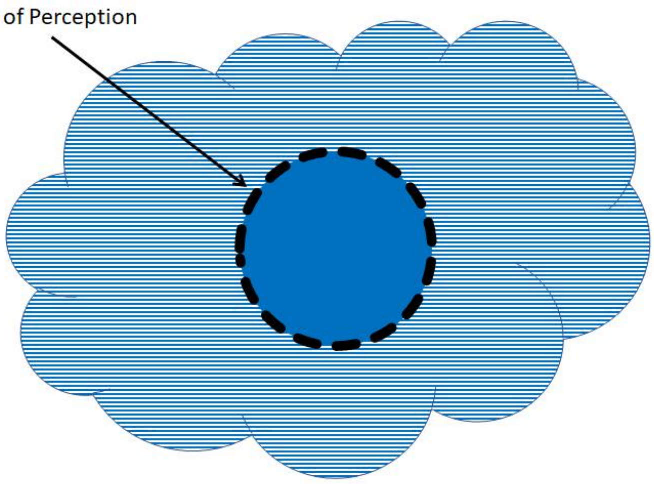


Figure 22. The effect of size on human perception.

We can only perceive a part of large things that are close to us. Physical distance is necessary if we are to perceive the whole.

In practice, the starting point in our search for understanding was reality at the human scale, i.e., the world in which we live and its direct impacts upon us. From here, the search has not only been in the upward direction towards ever greater complexity, but also in the downward direction towards ever less.

There are also practical limits to our perception of the very small and, thus, to our understanding of it. Nevertheless, both processes are ongoing, and the more we understand what underlies the sub-atomic world, the more this increases the complexity above it.

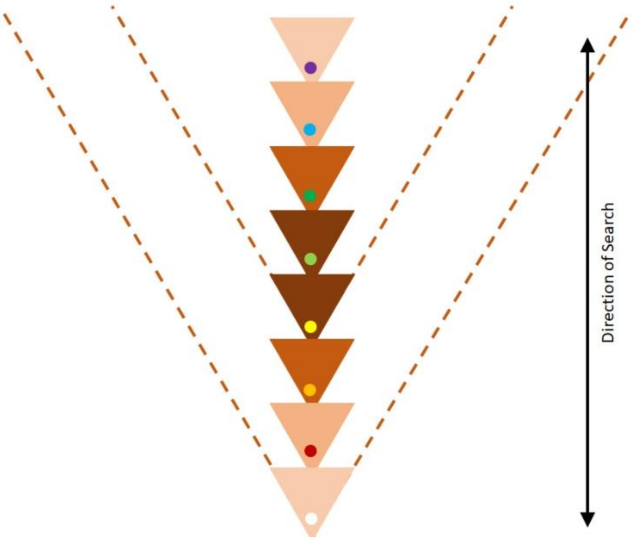


Figure 23. The Search for knowledge in practice.

JJ. Life.

A fundamental feature of living things is their use of information. Causes can transfer information, and, in life, this can result in an effect. People and other living organisms react to information either by processing it or exhibiting behaviour because of it. Rocks, sheets of metal, and planets do not. This response to information is the basic emergent property that defines life.

In non-living things, stability depends on geometry and forces being in balance. This does, of course, raise the questions: “What is a stable living structure?” and “What part does information have to play?”. The answer lies in self-maintenance. Living things are inherently unstable and constantly changing. However, information enables them to carry out self-maintenance and this creates a form of stability. Imagine, for example, a tightrope walker. When information from his senses tells him that he is beginning to lose balance, he will adjust his pole to correct it. This is a regulating feedback process that depends on information, and that is constantly in play throughout the tightrope walk. Similar feedback processes proliferate in a living being. Together they constitute self-maintenance, the anti-entropic feature of life.

From self-maintenance develops autopoiesis, the organism’s definition of its own boundaries, or “what is me”. People define the boundaries of a non-living thing by optimising its information content. However, the boundaries of living organisms are defined by what must be maintained. Cells, for example, have evolved membranes on their boundaries to contain and protect themselves.

In higher living organisms, self-maintenance can also include responses to information about changes in the environment. These are, of course, a survival trait and become ever more sophisticated as we ascend the evolutionary tree. Thus, a second boundary forms. Not only do we maintain “what is me” but also “what is mine”.

Social species such as humanity go on to develop boundaries around “what is us” and “what is ours”, and around “what is them” and “what is theirs”.

Finally, self-maintenance is now becoming a feature of machines and other artefacts designed by human beings.

5. General System Theory

General System Theory is probably best defined by a quote from one of its founders, the Austrian biologist, Ludwig von Bertalanffy: "...there exist models, principles, and laws that apply to generalized systems or their subclasses, irrespective of their particular kind, the nature of their component elements, and the relations or ‘forces’ between them. It seems legitimate to ask for a theory, not of systems of a more or less special kind, but of universal principles applying to systems in general." (von Bertalanffy, 1968).

A scientific theory normally begins life as a precisely stated but often speculative hypothesis. We then design experiments to support or refute it. However, what von Bertalanffy proposed is a hypothesis about a theory. Unfortunately, the only way to test his hypothesis empirically is to produce the theory. Failing to produce it does not disprove the hypothesis. In other words, what von Bertalanffy proposed cannot be dis-proven.

As things presently stand, a General System Theory either does not exist, or if it does, no-one recognises the fact.

In his paper “An Outline of General System Theory (1950)”, von Bertalanffy offers several isomorphisms as evidence for a General System Theory (von Bertalanffy, 1950). The term isomorphism means the same structure in different places. In this context, it means the same structure in different laws in different disciplines. The examples von Bertalanffy cites are:

- The law of exponential growth or decay, i.e., the rate of growth or decay of a parameter is proportional to the value of the parameter.

- The logistic law, i.e., the increase in a parameter, although initially exponential, is limited by some restricting conditions.
- The parabolic law. This describes competition within a system, each element taking its share according to its capacity, as expressed by a specific constant. The parabolic law underlies Pareto's law of the distribution of income within a nation, i.e., that roughly 20% of the population receive 80% of the income.
- The principle of least action, i.e., that true motion is the optimum out of all possible motions.

However, these principles are very fundamental, underlying even physics. So, one would expect them to apply in every discipline where physics has a part to play.

Von Bertalanffy offered one further isomorphism which cannot be expressed mathematically. This is:

- "…the formation of a whole animal out of a divided sea-urchin or newt germ, the re-establishment of normal function in the central nervous system after removal or injury to some of its parts, and gestalt perception in psychology."

However, this unnamed principle applies only to life, and has probably emerged with life.

It is in our nature to seek order in the world around us, but we can sometimes be led astray by cognitive biases. We have evolved a powerful ability to quickly recognise recurring structure. However, like all evolved traits, this ability can sometimes lead us astray. A similar evolved trait, known as the "hyperactive agency detection device", was proposed by the American psychologist Justin Barrett (Barrett, 2004). This trait enables us to quickly recognise stalking predators without conscious thought. Unfortunately, because it is hyperactive, it also causes us to believe that there is agency in things which, in fact, have none. It is, therefore, thought to be a significant cause of our religious nature. The same seems to be possible when it comes to our powerful ability to recognise structure. We may unconsciously sense similarities of structure when in fact there are none. We may also have an unconscious expectation that there is just one structure underlying all others. In other words, we may have an unconscious bias which causes us to seek a "theory of everything".

There are, however, reasons to doubt that a "theory of everything" is possible. It may be that there is no single set of laws applicable to all systems. Rather, there may be multiple, wholly independent laws that interact to create the universe we know. So, for example, human social systems will have their own set, some of which are shared by less complex levels, and some of which are particular to the discipline.

Because physical laws or scientific theories require a minimum amount of complexity before they emerge, they cannot also apply in a less complex field. So, the only similarities between sub-atomic systems and living systems, for example, will be those that rely solely on the laws of sub-atomic systems.

Furthermore, there are different paths of increasing complexity, with new laws emerging on each path. There is no reason to believe that the laws emerging on one path will share common features with the laws emerging on another. The only commonality will be features that depend on laws that emerged before the two paths diverged. Our inability to unify the four fundamental forces of physics adds weight to this argument.

Further weight is added by Kurt Godel's proof that there are infinite axioms in mathematics. Axioms are fundamental truths that are self-evident and cannot be proven. One axiom cannot be derived from another. Mathematics is a formal language and a subset of natural language. So, natural language must also have infinite rules. Natural language, in turn, is a reflection of human cognition, and so, there are also infinite rules of human cognition. Finally, human cognition is a reflection of physical reality, and so, there may be infinite laws in physical reality. This is not, of course, proof of the absence of a theory of everything. Rather it is evidence to suggest that there is not a single collection of laws from which all others can be derived.

6. Conclusions and Recommendations

The existence of a General System Theory cannot be disproven. However, the evidence suggests that there is not one in the form of a "theory of everything".

A General System Theory may be possible but based only on causality and the fundamental principles that underlie physics. However, because new laws emerge for more complex disciplines and more fundamental laws are often subsumed, its usefulness will be limited, and cannot be regarded as a "theory of everything".

To aid the pursuit of a general system theory, the following are recommended.

- Conceptual and theoretical frameworks are necessary to place any General System Theory on a firm foundation. Because such a theory must have very broad applicability, the components of these frameworks are likely to be very fundamental to the point of appearing naïve. Suggested frameworks based on this paper are begun in Appendices A & B.
- A possible way of testing for a theory of everything would be to map isomorphisms onto a diagram of the disciplines and the dependencies between them. This will be a tree like structure with particle physics at its trunk and more complex disciplines, such as ecology, on its branches, some of which may merge in places. One would expect isomorphisms as one ascends the hierarchy of complexity because of the dependencies between disciplines. However, isomorphisms that occur in separate branches, without also occurring before those branches diverge, would suggest that there may be a theory of everything.
- Causality appears to form a major component of any General System Theory. This is because it governs the interactions between systems and is either universal or emerged at the lowest level of complexity. A study of causal relationships in isomorphisms may therefore lead to a greater understanding of causal structures. This may, in turn, lead to the identification of isomorphisms between emergent properties. For example, regulating feedback loops may be necessary to create stability, and thus, systems.

However, in the absence of a General System Theory, the author advocates that effort be focused on the development of a social systems one to address the threats that humanity currently faces from war, climate change, and biodiversity loss.

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Appendix A – A Conceptual Framework for Systems Theory

The preferred definitions given in this paper are as follows and can form the basis of a conceptual framework for systems theory.

- **Space-time.** A single continuum comprising three dimensions of space and one dimension of time.
- **Physical.** Any matter or energy existing in a region or regions of space-time.
- **Entity.** Any concrete or abstract physical thing, including characteristics, relationships, and events.
- **Meaningful entity**. Any entity in which we recognise a structure that recurs.
- **Metaphysical.** Not existing in space-time. i.e., not physical.
- **Set.** Any group of entities treated as a singular entity.
- **Collection.** Any plural group of entities.
- **Characteristic or property.** Any feature common to different entities that we use to draw them together into collections.
- **Aggregation.** The conversion of a collection into a set.
- **Disaggregation.** The conversion of a set into a collection.
- **Abstract entity.** A physical entity with a boundary that is discontinuous in space-time. Those parts that contained within a continuous boundary are separated and distributed in space-time such that we cannot observe the entity in its entirety.
- **Relationship**. A physical thing comprising two physical entities for so long as the stated relationship between them exists, together with anything transferred from the one to the other and vice versa, whether it be space, matter, raw energy, or information.
- **Network**. A group of relationships between a collection of physical entities.
- **Event.** Any spatio-temporal relationship in which something earlier does something to something later. So, an event is physical in nature and comprises two physical entities, together with whatever passes between them.
- **Emergent property**. A feature or characteristic of a physical entity that its component parts do not have.
- **Holism** describes the emergence of new properties as entities are aggregated into greater entities in a hierarchy of complexity. Thus, a holistic entity is one with emergent properties.
- **Holon.** Arthur Koestler originally described a holon as being any entity that can be recognised as a whole in itself and which constitutes part of a larger whole (Koestler, 1967). However, for the purpose of this framework, a holon is also a meaningful physical entity with emergent properties that is the aggregate of a collection of other holons.
- **System.** Any meaningful physical entity with inputs, outputs, processes, and emergent properties, irrespective of its lifespan. Both holons and systems can be aggregated and disaggregated to form other holons or systems. Thus, a system is a holon and a holon is a system.
- **State.** A state is the set of characteristics that apply to an entity.

- **Change of state.** If the set of characteristics that apply to an entity changes for any reason, this is known as a change of state.
- **Structure.** Patterns or states of organisation in the way that the parts of an entity are related.
- **Static structure.** A state of organisation that persists from a human perspective.
- **Dynamic structure.** If an entity has a dynamic structure it is in a state of change but the change taking place is not random, as would be the case with a decaying building. Rather, it is ordered, occurring for example in cycles.
- **Causality or causation.** A theory comprising events known as causes and effects that describes the flow of matter and energy in the universe.
- **Necessary cause.** A cause in whose absence a stated effect cannot take place.
- **Sufficient cause.** A cause in whose presence a stated effect must always take place.
- **Linear causality.** This is causality at its simplest, comprising a single sufficient cause, and a single effect.
- **Domino causality.** A chain of linear causality leading to the sequential unfolding of events over time.
- **Cyclic causality.** A chain of causality in which the types of entity alternate, for example, chickens and eggs.
- **Positive feedback loop.** A circular or, more correctly, spiralling chain of causality in which an increase in a variable characteristic of each cause results in an increase in a variable characteristic of its effect.
- **Negative feedback loop.** A circular or, more correctly, spiralling chain of causality in which a decrease in a variable characteristic of each cause results in a decrease in a variable characteristic of its effect.
- **Regulating feedback loop.** A circular or, more correctly, spiralling chain of causality in which an increase or decrease in a variable characteristic of each cause results in a matching increase or decrease a variable characteristic of its effect.
- **Relational causality.** The relationship between two entities acts as a cause. For example, if one entity has a mass greater than the other, then the effect occurs but not otherwise.
- **Mutual causality.** In mutual causality two entities affect one another, for example a flea causes an effect in a dog and vice versa.
- **Cascading causality.** In this structure, the components in a causal chain also affect an entity outside of the chain, steadily amplifying or reducing a variable characteristic, for example, the familiar human practice of “digging oneself into a hole”. Like feedback, cascading causality can be positive or negative.
- **Function.** The function of a system can be regarded as its outputs. However, because these outputs are inputs for other systems, i.e., effects, these effects can also be regarded as the system’s function.
- **Purpose.** The purpose of a non-living entity is the same as its function. However, a living entity with agency can regard its purpose as being what it would like its function to be.
- **Physical law or theory.** A statement of a causal relationship in which entities of one type, the cause, always result in changes to entities of another type, the effect. Often, variations

in a characteristic of the cause result in variations in a characteristic of the effect. If so, then the law or theory can be expressed mathematically. However, this is not always the case and mathematics cannot always be applied.

- **Artifact.** Any system created by a living entity.
- **Needs.** The processes of a living entity or an artifact.
- **Satisfier.** An input to a living entity or an artifact that increases the ability of the latter's processes to produce their outputs.
- **Contra-satisfier.** An input to a living entity or an artifact that decreases the ability of the latter's processes to produce their outputs.
- **Recursion.** In systems theory, recursion refers to the fact that all systems can be disaggregated into more than one lesser system, and that all systems form a part of collections that can be aggregated into greater systems.
- **Granularity** describes the disaggregation of a system into component systems.
- **Level of Granularity.** The first level of granularity comprises the greatest component systems that together fully comprise the entity. The second level comprises the next greatest component systems that do the same, and so on.
- **Complexity.** The number of fundamental sub-atomic particles in an entity. For the present, at least, we can regard fundamental particles as those identified in the Standard Model of physics.
- **Hierarchy of complexity.** Something comprising levels, each of which is a number of fundamental particles.
- **Prototype.** A mental image of a typical member of a collection that has only the characteristics we have used to define that collection, and none of the variability.
- **Isomorphism.** In system theory the term isomorphism is used to describe two systems that have components with the same pattern of interactions. These components are also systems and because interactions between systems are causal, isomorphisms are systems that have the same causal patterns within them.
- **Chaos.** It is in our nature to understand systems in terms of their component systems and the interactions between them. Because systems do not emerge at all levels of complexity, as the level of complexity increases, the number of interactions between entities whose properties have emerged at a lower level also increases. Ultimately, the number of interactions can overwhelm our ability to make sense of the world and the situation can appear chaotic.
- **Simplification.** This is the process of bringing the interactions between components back within the limits of our mental capacity, thus, reinstating a degree of predictability. Typically, simplification involves placing entities into broader categories using fewer shared characteristics or we may use value ranges for variable characteristics to which a numerical value can be given. In this way, the number of entity types is reduced, and so too are the number of relationships between them.
- **Discipline.** A field of knowledge with its own distinct entities and laws governing the relationships between them.
- **Entropy** is a measure of disorganisation in an entity or of the number of ways in which particles can be arranged in it consistent with its large-scale general condition.

- **Open system.** One that receives inputs and delivers outputs.
- **Closed System.** One that receives no inputs and delivers no outputs.
- **Information.** Something that is inherent in the structure of entities in space-time whether they be matter, energy or both.
- **Information at source.** Information within the entity that it describes. An entity's components do, of course, have their own information content or descriptions. These do recur within the entity, but they are descriptions of the components rather than of the entity itself. Thus, they are not included in the entity's information at source. Thus, information at source is the structure inherent in the first level of granularity, i.e., in the least granularity that displays that structure just once.
- **Recognition.** The process of replicating and translating information at source into the medium of the recogniser.
- **Life.** A fundamental feature of living things is their use of information. Causes can transfer information, and, in life, this can result in an effect. People and other living organisms react to information either by processing it or exhibiting behaviour because of it. Rocks, sheets of metal, and planets do not. This response to information is the basic emergent property that defines life.
- **Self-maintenance**. A regulating feedback process that employs information.
- **General system theory** is probably best defined by a quote from one of its founders, the Austrian biologist Ludwig von Bertalanffy: "...there exist models, principles, and laws that apply to generalized systems or their subclasses, irrespective of their particular kind, the nature of their component elements, and the relations or 'forces' between them. It seems legitimate to ask for a theory, not of systems of a more or less special kind, but of universal principles applying to systems in general." (von Bertalanffy, 1968).

Appendix B – A Theoretical Framework for Systems Theory

The laws of system theory described in this paper are as follows. They form the basis of a theoretical framework. However, no attempt has been made to identify which are axiomatic and which are not.

Entities

- Everything that exists does so in a region or regions of space-time.
- Systems and holons are the same things.
- Systems are a proper subset of meaningful entities.
- All systems have emergent properties.
- The appearance of an entity is not an emergent property.
- All systems are dynamic.
- All systems are, by definition, open systems.

Relationships

- Relationships are physical entities.
- Every relationship comprises two systems and whatever passes between them for so long as the stated relationship exists.
- Relationships can be systems but are not necessarily so.
- Physical laws and theories, including causality, are a subset of all relationships, and the same principles apply to them.
- Individual relationships have a simple recognizable structure and almost certainly recur. They are meaningful entities, therefore. However, they are not necessarily systems because they do not necessarily have emergent properties.
- There must be a minimum number of relationships between component systems before a higher level system is formed, i.e., before a property other than a change in appearance emerges. This emergent property can be an output from the system, which in turn, can be the basis for relationships between higher level systems.
- Relationships form networks. The more relationships in a network, the less likely it is to have a recognizable structure that recurs. So, the less likely it is to be a meaningful entity and the more likely it is to appear chaotic.

Recursion

- Systems form a nested hierarchy, i.e., they can be disaggregated into more than one lesser system and more than one can be aggregated into a greater system.
- There may be a lower limit to recursion. The lowest level of recursion, known to us at present, comprises the fundamental sub-atomic particles and the four fundamental forces of physics. The latter are the strong nuclear force, the weak nuclear force, the electro-magnetic force, and gravity. For the present, at least, these particles appear not to comprise lesser particles, and the forces not to comprise lesser forces.

Feedback Loops

- A positive feedback loop must have inputs because variable characteristics of its components are increasing.

- A negative feedback loop must have outputs because variable characteristics of its components are decreasing.
- A regulating feedback loop provides stability, i.e., variable characteristics of the components in the loop remain the same or oscillate about a mean. This would suggest that stable self-maintaining systems must also contain feedback of this nature.

Complexity

- The complexity of a relationship is the sum of the complexity of its two components.
- The level of complexity of a system increases and decreases during its life. This is due to ongoing inputs and outputs. Ultimately, most systems disappear entirely, i.e., their level of complexity becomes zero. Some can self-maintain within a range of levels of complexity for a time. Others can disappear entirely after a very short life.
- The second law of thermodynamics states that, in a closed system, as energy is transformed from one state to another, some is wasted as heat. Importantly, however, the second law also states there is a natural tendency for any isolated system to degenerate from a more ordered, low entropy state to a more disordered, high entropy one.
- Based on the assumption that the entire universe is a finite closed system, overall, entropy is thought to be increasing and the universe becoming ever more disorganised. Thus, we cannot expect everything to be a structured and recognisable entity.
- Interactions can take place and relationships can exist between systems that occupy different levels of complexity.
- As entities become more complex so too do their potential characteristics. Thus, characteristics emerge with the increasing complexity of entities.
- As entities become more complex so too do their potential relationships, i.e., what they receive from and pass to other entities. Thus, types of relationship emerge with the increasing complexity of entities.
- Novel properties and thus systems do not emerge at all levels of complexity. They only emerge when there are a sufficient number of fundamental particles in an entity, and they are related in a particular way.
- Different properties emerge at different levels of complexity. This is because increasing complexity permits a larger number of fundamental particles to be related in a more complex way.
- Types of system do not all emerge at the same level of complexity. Rather they occur within a range of complexities. Molecules, for example, can vary in complexity from a simple hydrogen molecule to DNA, and the number of sub-atomic particles in each differs substantially.
- Between the levels of complexity at which stable structures emerge, entities have an unstable static structure that, by definition, is in a state of change.
- New properties can be new physical laws. This is because physical laws are causal relationships between systems. These causal relationships are determined by what is transferred from one system to the other. As the complexity of the source entity increases what is transferred can also increase in complexity. This is because it was a part of the source entity.
- The laws and theories that emerge for a discipline cannot apply to disciplines at lower levels of complexity.

- Simplification can only be carried out without introducing error by using fewer higher level systems in which new properties have emerged.

Paths of Increasing Complexity

- Disciplines emerge on different pathways of increasing complexity.
- If the universe were finite, then all paths of increasing complexity would merge when the level of complexity reaches the universe in its entirety. At this point, all physical laws and scientific theories would interact to form the universe as a whole. However, the universe is probably infinite and, were it not for the limitations imposed on causality by the speed of light, new properties and disciplines would emerge indefinitely.

Granularity

- As the level of granularity increases the number of components systems of a system increases and their complexity decreases.
- Although a system emerges at a particular level of complexity, not all of the component systems that form it emerge at a common level of complexity. Rather they emerge over a range of levels. So, for example, the first level of granularity is determined by the level of complexity at which the final greatest component system emerges. Fortunately, such ranges are relatively narrow in comparison with the total range of complexity.

Isomorphisms

- Two isomorphic entities do not necessarily have identical components. Nor do those components necessarily have the same arrangement in space. Furthermore, what is transferred between those components is not necessarily the same. Isomorphic entities do however have the same number of components and the same pattern of causal relationships between them.
- Isomorphisms between disciplines are based on properties that have emerged at a lower, common level of complexity.

Information

- Because information is order inherent in matter and energy, an item of information occupies a region of space-time.
- Information is recursive. Any item of information comprises lesser items and is a part of greater items. Some of these items are meaningful, whilst others are not. Only the former are information.
- The least or atomic component of information at source is a meaningful physical entity.
- The least or atomic component of translated information is any symbol representing a meaningful entity, e.g., a word.
- The molecular component of information at source is a relationship between two meaningful entities.
- The molecular component of translated information is a relationship between meaningful entities, e.g., a proposition in logic or a sentoid in natural language.
- For an entity to be meaningful, its information at source must recur elsewhere.
- Information can be transmitted from place to place causally via media known as channels.
- Information is translatable. Structure in one medium can represent, rather than replicate, a different structure in another.

- Information can be replicated, whilst raw matter and energy cannot. Structure in one place can be copied to another. The term “replication” is used because information is established in the latter place, whilst also being retained in the former.
- Information at source can be replicated, but in doing so it must also be translated.
- Once information at source is replicated and translated, i.e., recognised, the result may be replicable.
- The process of replication and translation is only carried out by living entities and some of their artifacts.
- For an entity to be recognised, its information at source must be translated and replicated in the mind of the recognising agent.
- The more ordered the elementary components and relationships within an entity, the greater the likelihood of it recurring and being recognised.
- The more complex an entity, the greater its size, and the greater its size, the less the likelihood that we will be able to perceive it. Furthermore, it is less likely that an entity’s structure will recur within a timeframe that allows us to recognise its recurrence.
- The perception and information processing abilities of living entities and their artifacts is limited. So, in translating and communicating we simplify; we assume; we make mistakes; we reject or modify new information that is not consistent with our existing knowledge; and so on. Thus, information can be false.
- Information at source is, by definition, always true. However, replicated information can be true or false.
- In a closed system, any structure held by matter and energy, for example information, must decrease with time. This includes information at source or in replicated form. So, information, naturally decays unless it exists in an open system and is maintained. Meaning is lost through errors of transmission. Individuals and societies forget.
- One way in which information can be altered is by noise in the channel by which it is transmitted.
- The decay of information can be minimised by redundancy. Redundancies can comprise repetition of the same component of information or duplication of the channels through which it is transmitted. They can also comprise recursion, i.e., the same component of information repeated at different scales.
- Information can contain irrelevances, i.e., meaningless components which have no influence on the information content of the entity. Thus, when irrelevances or redundancies exist, information can be condensed without any loss of meaning.
- A modified principle of darkness would state that no system can be known completely by anything insufficiently complex to hold its information in a condensed form. Failing that, the information must be simplified and will, therefore, contain errors.
- The transfer of information can provide a basis for establishing the relationships needed for a stable structure.
- Information enables living entities and some of their artifacts to carry out self-maintenance via regulating feedback loops and this creates a form of stability.
- Entropy is not the reciprocal of information at source. Entropy is understood in physics to be disorder at every level of an entity from the molecular or atomic level upwards. It is,

therefore, the reciprocal of information at all levels, i.e., of the total information in an entity and in all its parts. It is not the reciprocal of information at just one particular level, as used in human reasoning.

