Complexity

English

1. Futures definition

Complexity is a property of anticipatory systems displaying high degrees of diversity, interactivity, interconnectivity, relationality, nonlinearity, and unclear causalities. In complex systems, access and perspective are often localized. Due to sensitivities to internal and external conditions and extreme events, unpredictable circumstances may arise within and between complex systems, leading to insecurity and uncertainty. Importantly, complexity can also open pathways to sense-making, adaptation, innovation, evolution, emergence, and resilience.

2. General definitions

In a general sense, complexity refers to “the quality or state of being complex” (Merriam-Webster, n.d.-c). Fundamentally, complex systems are distinct from complicated systems, which “can be – at least in principle – fully understood and modeled” (Poli, 2017a, p. 186). A complicated system, such as a car, can be difficult or confusing as a set of individual parts but is ultimately comprehensible and controllable. A complex system, on the other hand, consists of many interacting and dynamic parts and “cannot be explained by means of a simple theory” (Cilliers, 1998, p. ix).

Complexity often arises as a result of dynamics between the parts of the system across time and produces a “collective emergence of new properties and behaviors” (Poli, 2017, p. 10). These system dynamics create an environment of ongoing internal and external changes, which create additional system changes in turn. As a result, complex systems must be contended with in a consistent, ongoing manner rather than by examining or addressing individual components at one point in time (Miller, 2018; Snowden, 2024). Because complex systems “evolve through time, [and] their past is co-responsible for their present behavior” (Cilliers, 1998, p. 4), “their internal structure reflects their history” (Juarrero, 2010).

As the study of complexity and complex systems continues to evolve, actual definitions may be inflected by many disciplines and areas of focus, ranging from mathematics, computer science, and the natural sciences to the humanities, sociology, philosophy, pedagogy, and more.

3. Etymology

The Proto-Indo-European root *plek-* gives rise to Latin *plecto*¯and Greek *ple'ko,* which mean braid or plait (Mallory & Adams, 1997). The Latin prefix *com-* means "with, together", while the archaic *cum-* expresses "together, together with, in combination or union" (Online Etymology Dictionary, n.d.). Thus, the compound Latin verb *com-plectere* means "plaited together, interwoven" and *complecti* means "to entwine around, to embrace" (Latin Dictionary io, n.d.), while *complexus* (masculine) and *complexa* (feminine) mean "encircle, encompass" (Latin Dictionary io, n.d.). Latin descendants include the French word *complexe*, which means "not simple (Wiktionary, n.d.-b), and the English term complexity, which is formed by adding *complex* and *-ity* (condition or quality of being) together. These historic origins and definitions of the term reflect the interactivity, nonlinearity, and interconnectedness inherent to complex systems.

4. Field of terms

As an essential distinction from everyday usage, *complicated* and complexity can be considered antonyms in futures studies (Snowden, 2024, p. 52). Additional antonyms to complexity that are specific to futures studies include *order*, *obviousness*, and *clarity* (Nachbagauer, 2021), while general usage of the term complexity includes the antonyms *uncomplicated*, *simplicity, uniformity,* and *homogeneity* (Merriam-Webster, n.d.-c).

In English, synonyms for complexity include *complexness*, *diversity*, *elaborateness, heterogeneity*, *heterogeneousness*, *intricacy*, *intricateness*, and *multifariousness*, among other terms (Merriam-Webster, n.d.-c). Meanwhile, the presence of complexity can be signalled by the following words or word components: *'multi', 'bi', 'poly', 'dual', 'mega', 'co-', 'mixed', 'blended', 'inter', 'cross', 'ambiguous', 'reciprocal', 'fuzzy', 'agile', 'flexible',* or *'ad hoc'* (Translated by authors from Reiss, 2020, p. 32).

The term complexity entails an extensive taxonomy that includes complexity frameworks, theories, and thinking (Miller, 2018, p. 103); complex systems that may also be *impredicative*, *anticipatory*, *dynamic*, *adaptive*, *evolving* or *evolutive*, and *autopoietic* (Rosen, 2012; Poli, 2017b; Cilliers, 1998; Juarrero, 2010; Aaltonen, 2005; Miller, 2018; Maturana & Varela, 1980); and complexity sciences, which can be further taxonomized under five primary intellectual traditions: mathematical complexity, systems theory, complex systems theory, cybernetics, and artificial intelligence (Castellani & Gerrits, 2021). Because the term complexity has so many meanings (Louie & Poli, 2019, p. 18), relational biologists Robert Rosen and his student A.H. Louie, in the development of their mathematical models and theory of anticipatory systems, prefer impredicative – or the "property of a self-referencing definition" of a system as a synonym for complexity (Louie & Poli, 2019, p. 202).

Murray Gell-Mann, a Nobel Prize-winning physicist and co-founder of the Santa Fe Institute, which studies complex systems, proposed the term *plectics,* based on the word root *plek-*, for the study of both complexity

and *simplicity* (2002).

The term *chaos, which* refers to “a state of confusion”, “confused mass or mixture”, and “the inherent unpredictability in the behavior of a complex natural system” (Merriam-Webster, n.d.-b), is distinct from but adjacent to complexity. This distinction exists in part because of the role of chance in unpredictability and emergence in chaotic systems. Additional terms include *edge of chaos, which* reflects the border of a system between order and chaos (Mitchell, 1993, p.1), and *chaoplexity*, which signifies “the confluence of chaos and complexity” (Wiktionary, n.d.-a).

5. Theoretical foundations

The work of futures scholars, especially in foundational texts such as *Introduction to Anticipation Studies* by Roberto Poli (2017b) and *Transforming the Future: Anticipation in the 21st Century* by Riel Miller (2018) and others, builds on the important roles of Rosen and Louie in developing a theory of anticipation. Therefore, complexity in futures work is frequently discussed in terms of anticipatory systems, and Rosen and Louie’s preferred term, impredicative, can be used. Miller states that “for Rosen, systems either are complex or not” (2018, p. 88), which is also to say that they are either impredicative or predicative.

While this glossary defines complexity as being a property of an anticipatory system, this definition only serves as an entry point into a general understanding of the term in futures studies. Rosen, for example, somewhat contradicts this glossary’s definition, arguing that "complexity is not an intrinsic property of a system nor of a system description. Rather, it arises from the number of ways in which we are able to interact with the system. Thus, complexity is a function not only of the system’s interactive capabilities, but of our own” (Rosen, 2012, p. 298). This interactivity between individual or collective selves and complex systems may inherently localize some understandings and experiences of complexity. For example, one person may see and interact with a landscape as a collection of geologic and atmospheric features while others may be able to see, articulate, and interact with many additional layers in the same landscape, such as animal and human history, soil quality, hydrologic understandings, environmental sustainability concerns, and more, which increases the system’s perceived complexity, or the number of ways in which some individuals could interact with that same landscape.

Beyond Rosen and Louie’s usage of the terms impredicative and anticipatory, futures work includes other terms for describing and discussing complex systems. For example, *autopoiesis* is the property that allows a living being to generate itself via circular organization (Merriam-Webster, n.d.-a).

Another important example is the term *complex adaptive systems (CAS)*, which refers to systems that “are found in fields as diverse as biology, economics, social sciences, and technology” (Jerab, 2025). These types of systems are “undergoing a kaleidoscopic array of simultaneous interactions” (Holland, 1992) and “seem to

share three characteristics: evolution, aggregate behavior, and anticipation" (Holland, 1992). Importantly, interactions in a CAS can be both the causes and effects of internal system adaptations and evolutions. Because of the networked assemblage of interconnected and interacting components in a CAS, these causes and effects can be both nonmaterial and nonlinear (Juarrero, 2010; Snowden, 2024), and "the system as a whole is modulated" (Snowden, 2024, p. 52). Discussing these system dynamics, Poli posits that "the most productive CAS is one which functions at the edge of chaos, where maximum variety and uncertainty spawn constant change, anticipation, and adaptation" (2019, p. 1668), while Snowden claims that "emergence is one of the most critical aspects of CAS and is frequently one of the most commonly misunderstood" (2024, p. 53).

In addition to CAS, some scholars use the term *complex evolving systems (CES)* (attributed to Mitleton-Kelly in Aaltonen, 2005, p. 16). In a CES, "the systems – social, cultural, technological, organisational – are not only adapting to the emerging conditions, they are co-evolving within them" (Aaltonen, 2005, p. 16).

Complexity also exists in many *biological entities*, including molecules, cellular organisms, and ecological systems (Mainzer, 2007, p. 8). Tuomi points out that complex systems are in a "constant state of becoming" (2018, p. 19), citing the biological evolution of wings in birds as an example. Snowden, on the other hand, utilizes the "concept of *exaptation* in which a trait that was selected according to one function under conditions of stress *exapts*, rather than adapts, for a completely different context" (Snowden, 2024, p. 54) via a "radical repurposing of existing capability for novel use" (Snowden, 2024, p. 51).

Complexity also exists in *social systems*. Poli understands humans as "highly complex and wonderfully sophisticated cognitive agents" (Poli, 2019, p. 5), and Juarrero states that "all social phenomena are complex systems", including *narrative* (Juarrero, 2010). In *educational contexts*, "learning can be a complex process where larger systems and individual components mutually influence each other" (Stamovlasis & Koopmans, 2025, p. 1).

Similar to Rosen and Louie's relational biology models, researchers in *complex dynamical systems (CDS)* use mathematical models to study subjects such as physics and economics (Dale, 2024, p. 1). Examples of CDS in physics and chemistry include atomic and molecular systems (Mainzer, 2007, p. 8). Meanwhile, in the field of *computer science*, networks on the Internet are considered complex systems (Mainzer, 2007, p. 8).

Despite efforts to standardize complexity as a research and knowledge domain, each of these disciplines and others utilize different methods and perspectives to understand, analyse, and model complexity, meaning interdisciplinary collaboration is often crucial to understanding complex phenomena and actualizing complexity thinking.

6. Use in practice

For futures practitioners, “complexity thinking provides permission to embrace uncertainty, to be open to complex emergence, at all points in time, even right now” (Miller, 2018, p. 103) and opens entry points into sense-making activities and an active engagement with the future via anticipation. While complex systems continuously emerge and change from past to present to the later-than-now, and “have a history” (Cilliers, 1998, p.4), they do not possess “clear and repeatable cause-and-effect relationships, but rather strong and changing dependencies on the people involved and the respective environment. As a result, there are usually no clear and best solutions or practices that can be developed by experts and always work” (Bergheim, 2022, p. 276).

Nonetheless, some frameworks, tools, and processes, including collective intelligence knowledge creation (CICK) processes, used in futures work can help futures practitioners develop a range of competences and effective practices. For example, Poli’s idea of the *thick present*, “in which pasts, presents, and futures engage in layered sense-making” (Bussey, 2019, p. 868), is helpful, as are Snowden’s *Estuarine Mapping and Cynefin Framework*. Developed in 1999, the heuristic Cynefin Framework is designed to help managers assess the complexity of situations for the purposes of developing appropriate strategies for action or problem-solving during project management contexts. The framework comprises five domains: At the centre is the domain of disorder, in which the approaches to assessing a situation or system may be unclear. The framework also includes obvious, complicated, complex, and chaotic domains (Nachbagauer, 2021, pp 1-5, The Cynefin Company, 2026). Similarly, Sohail Inayatullah’s *Causal Layered Analysis* offers a flexible analytical framework for making sense of complexity by examining “the four levels of the litany, social causes, discourse/worldview, and myth/metaphor” (Inayatullah, 2004). Meanwhile, the Futures Literacy Laboratory offers a lab-based approach for CICK processes to address a variety of challenges and opportunities across varying scales “[t]hrough exploring different types of futures – probable, preferable, and reframed” (UNESCO, n.d.). Those working in futures studies via engagement with complex systems may develop greater competence through these and other sense-making and CICK efforts (Miller, 2018, p. 74).

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This English text is the original entry for this term. No LLM has been used in the generation of this entry.

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