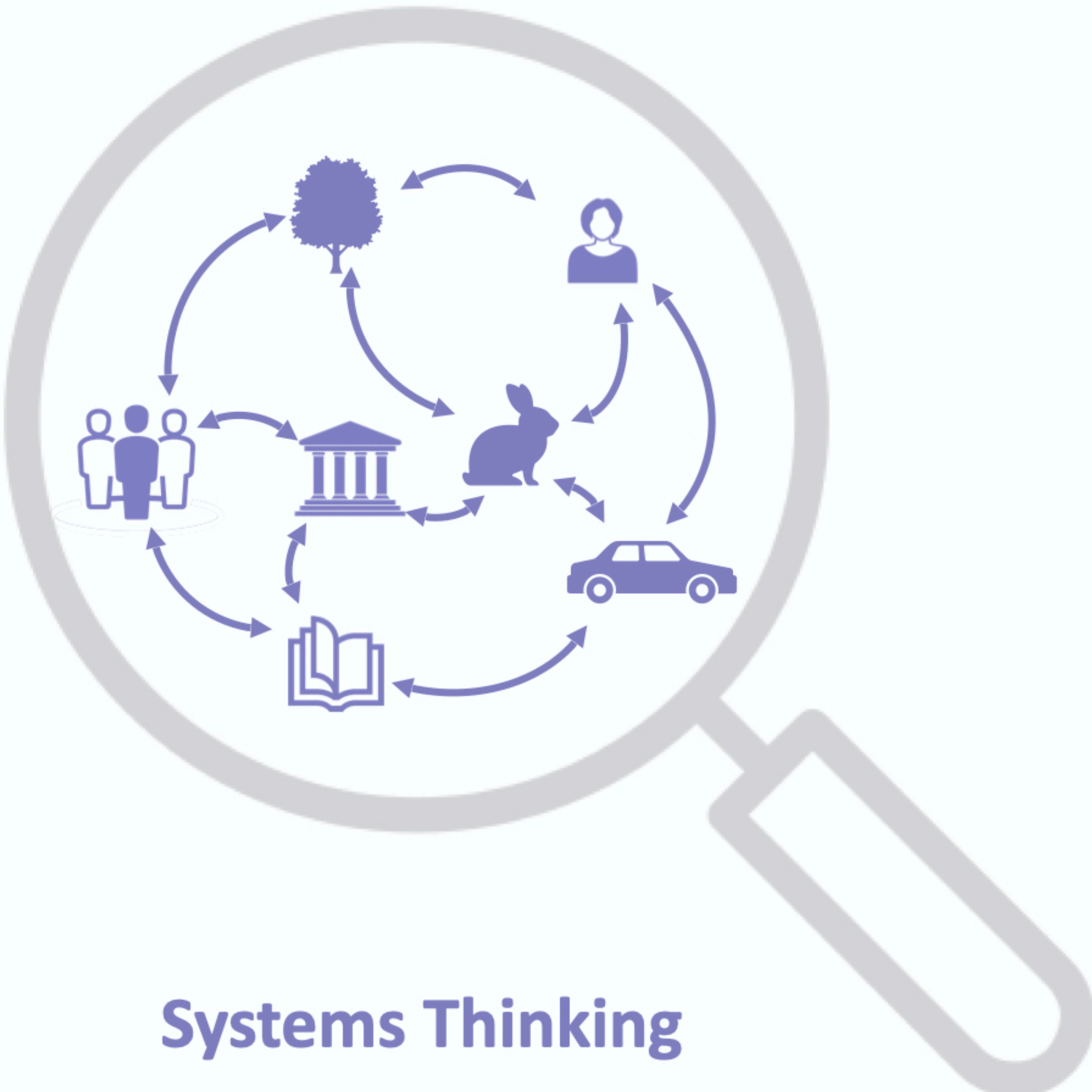
Systems Thinking

Systems thinking is a very broad area that seeks to bring together the many different ways of thinking that are holistic in their interpretation of the world to balance and complement a more analytical view of the world. Holistic thinking seeks to understand phenomena as intimately interconnected and comprehensible with reference to the whole system or environment they form part of. Systems thinking is: A synthetic modes of reasoning that looks at what emerges when we put things together rather than taking them apart. It is nonlinear way of looking at the world that focuses on relations of interdependence and feedback dynamics. It is a relational paradigm interpreting things in the context of the network of relations they form part of. It is a dynamic way of looking at the world, understanding change in terms of nonlinear feedback processes that shape system structure and outcomes

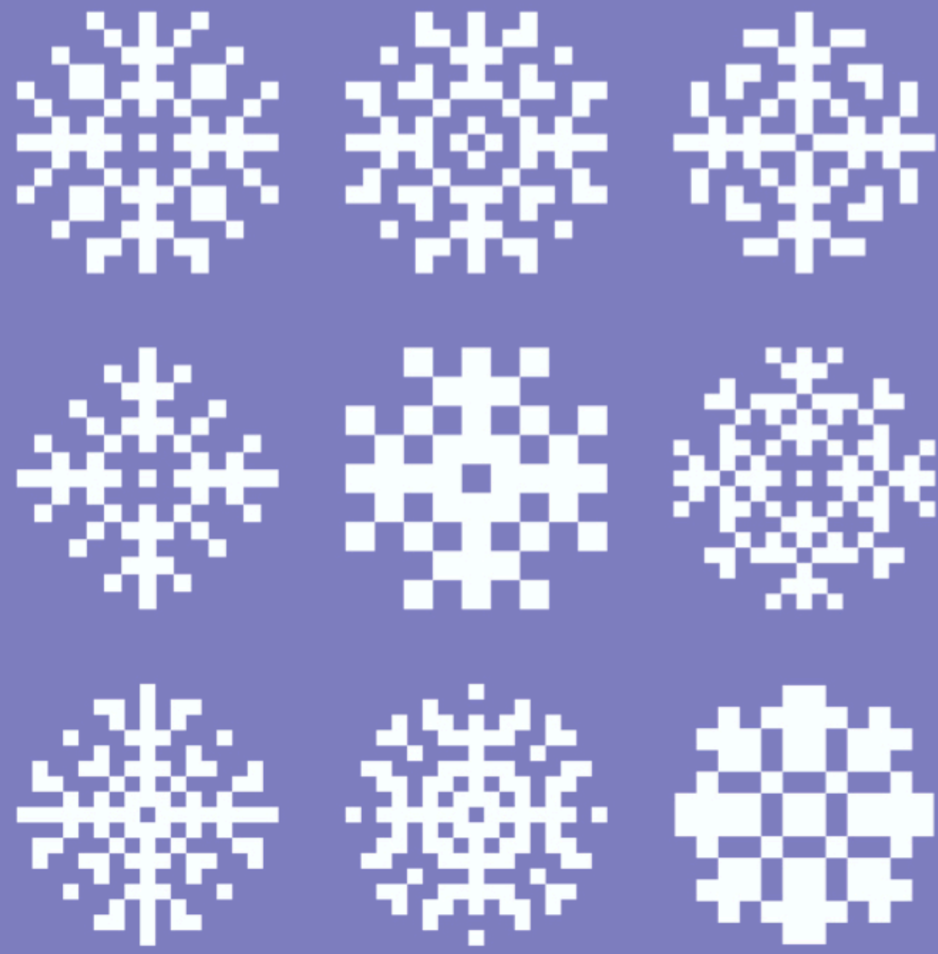
Analytical Thinking



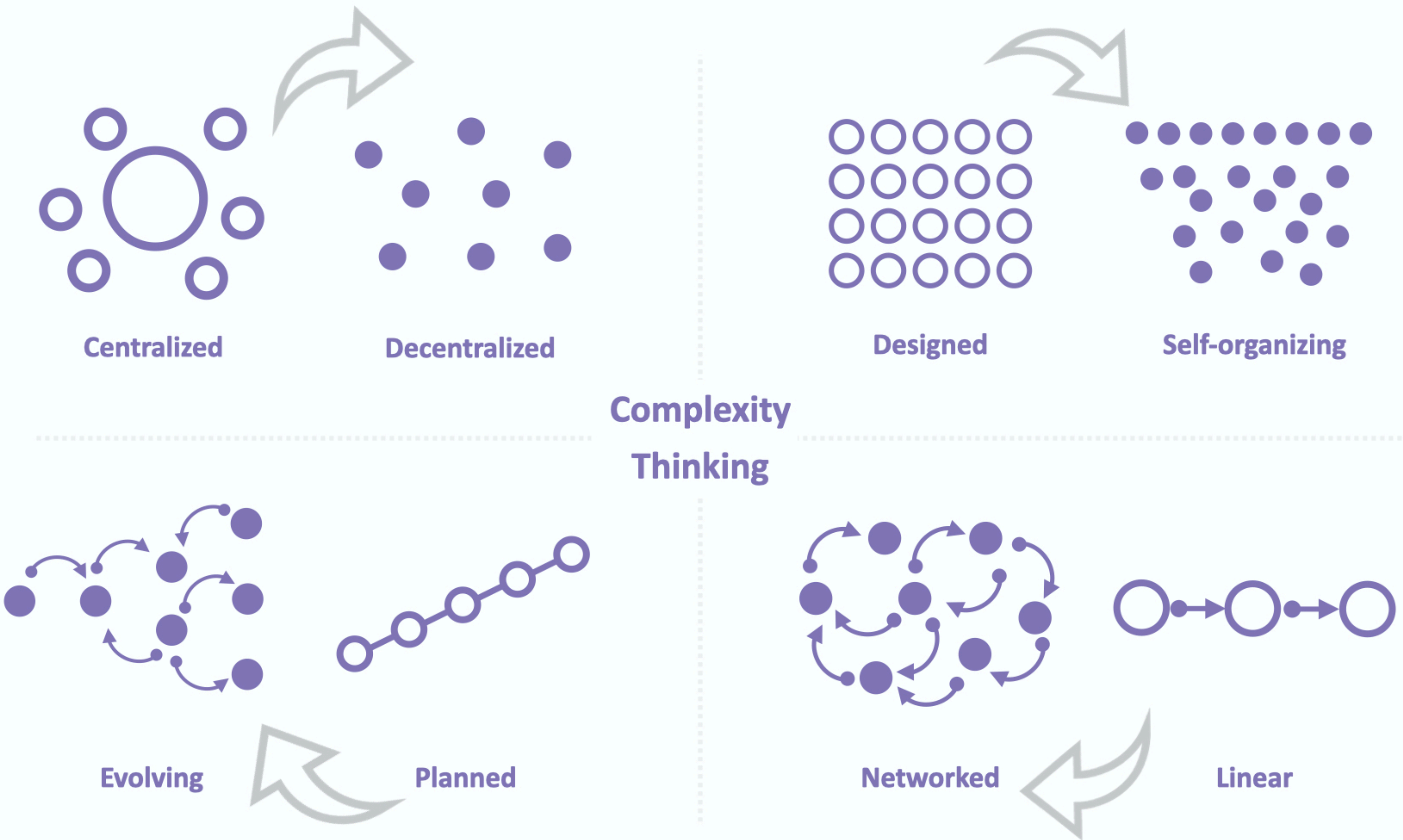
Systems Thinking

Complexity Theory

Complexity theory is a set of theoretical frameworks used for modeling and analyzing complex systems within a variety of domains. Complexity has proven to be a fundamental feature to our world that is not amenable to our traditional methods of modern science. As researchers have encountered it within many different areas from computer science to ecology to engineering, they have had to develop new sets of models and methods for approaching it.



Out of these different frameworks has emerged a core set of commonalities that over the past few decades has come to be recognized as a generic framework for studying complex systems. It can be understood as a composite of a number of major modeling frameworks that fall under its canopy including; systems theory; nonlinear systems; network theory; complex adaptive systems & self-organization theory.



Complexity

Complexity is a property of systems that have many diverse, and often adaptive, parts that are interconnected and interdependent in many ways to create emergent properties and dynamics. Examples of complex systems include conflict zones, cities, corporate supply chains, financial markets, or ecosystems.

All of these systems have a great many parts. These parts can have diverse properties, such as cultures or diverse creatures in an ecosystem. Elements likewise typically have adaptive capacity and network patterns emerge out of the local nonlinear interactions between the agents, such as traffic jams in a city.

Complex systems have the characteristics of being nonlinear with multiple feedback loops that allow for rapid change and make them unpredictable and highly dynamic. They are strongly defined by their network architecture and change over time through evolutionary processes.

Simple System

A set of hexagon tiles is a simple system because there are few parts that are all very similar without adaptive capacity and connected in a simple fashion. Anyone can understand simple systems.

Complicated System

A truck is a complicated system with many specific parts and sub-systems that are interrelated in many very specific ways. One needs to be an expert to understand these systems

Complex System

The global biosphere is a complex system as it consists of many diverse adaptive parts that are all interdependent and adapting to changes. To understand these systems you need a large amount of experience and insight from different perspectives

Principle 1

Holism

Holism refers to any approach that emphasizes the whole, rather than the constituent parts of a system. Holistic accounts of the world look for how an entity forms part of some larger whole and is defined by its relations and functioning within that broader system. What all holistic approaches have in common includes the principle that the whole has priority over its parts and the assumption that properties of the whole cannot be explained by the properties of its parts—the idea of emergence.

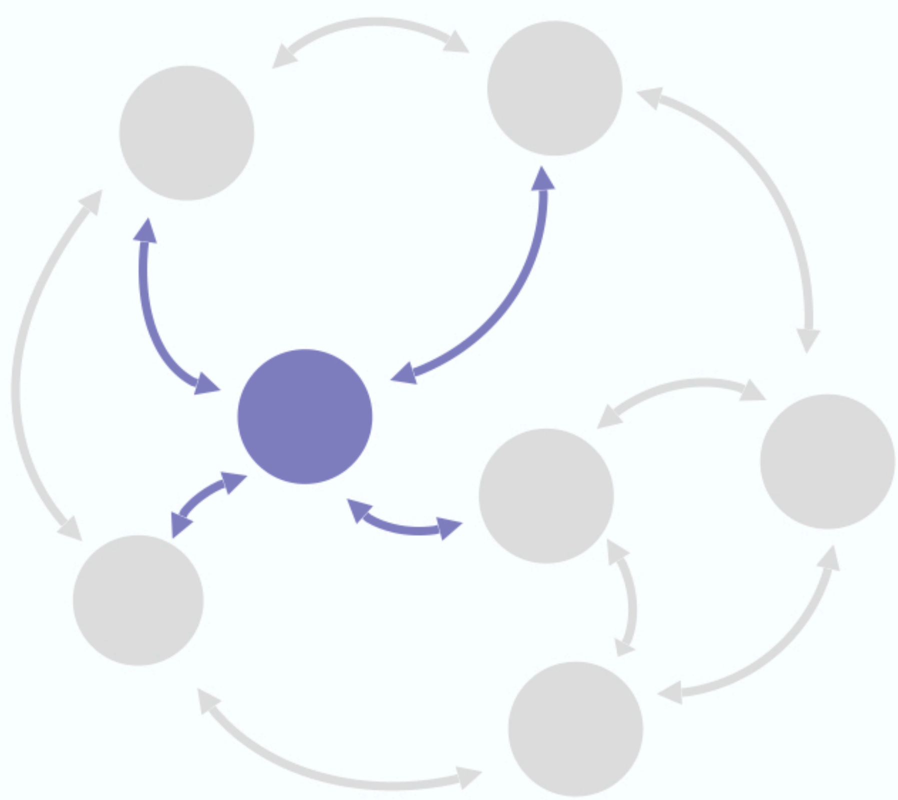
Within this paradigm, the ultimate sources of knowledge are seen to derive not from elementary component parts but, instead, from a reference to the system's broader context. Given that something can only be properly understood within its context, to gain a fuller understanding of something requires gaining a greater understanding of the environment or context.

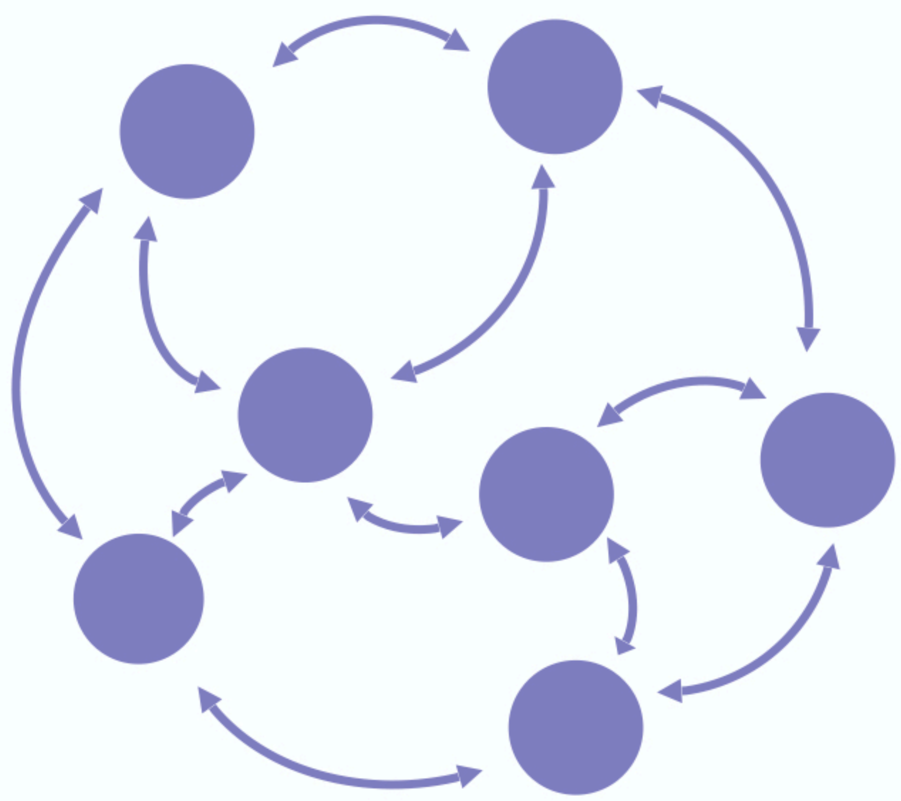
Analytical Reductionism

Reduce the complexity down by only focusing on the problem area, find the cause of it and change the cause to solve the problem.

Synthetic Holism

Expand outwards from the perceived issue to understand the structure of the system and the overall paradigm, then influence the parts and connections in the broader network to change the pattern.



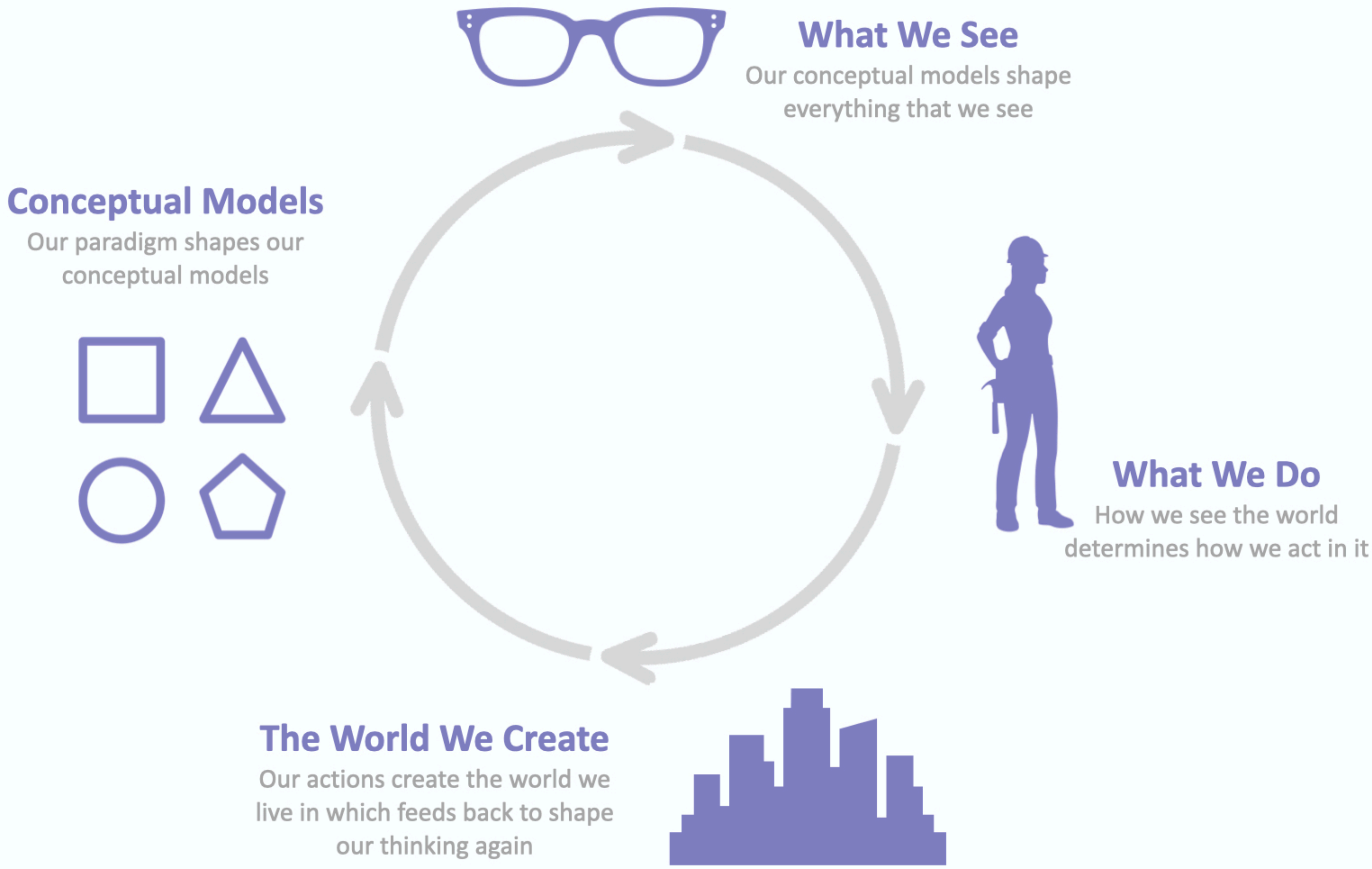


Principle
2

Reflexivity

Reflexive thinking is about becoming aware of how our thinking shapes what we see, do, and thus the world we create. Systems thinking requires us to surface our paradigms and mental models so as to be aware of how they work, what they will enable us to see and how they will inhibit us in seeing other things.

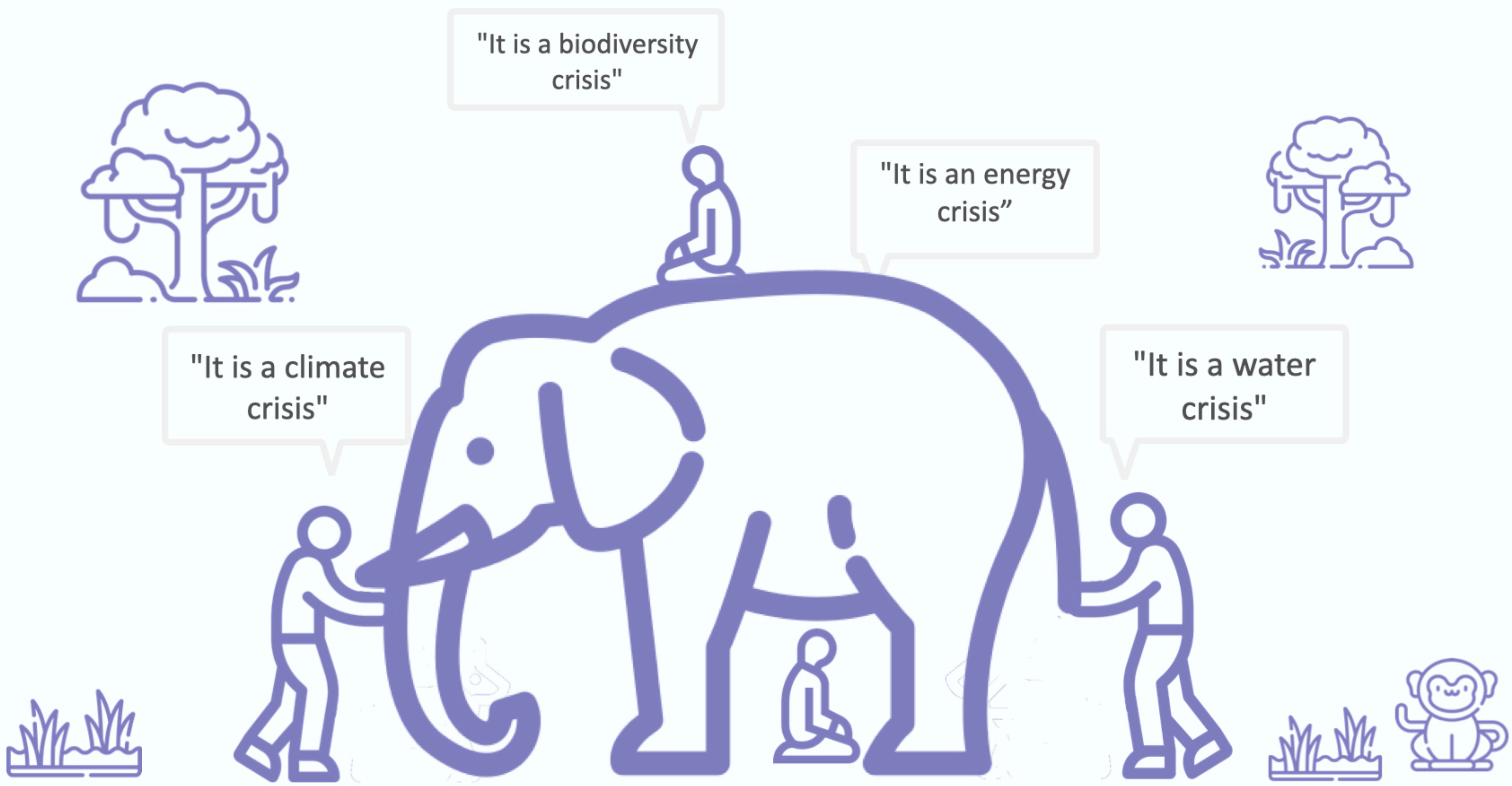
Being reflexive means examining and being aware of the assumptions we bring to what we do, that all of us hold opinions and preconceptions that are a product of what we have learned and our past experiences. Calling oneself a systems thinker is a commitment to an ongoing learning process of examining and trying to improve our mental models and thinking to become better at seeing systems. This starts with first understanding how we see the world, and the existing limitations of our thinking and assumptions.



Perspectives

Understanding and working with complexity requires that we build awareness through the synthesis of multiple perspectives. "A systems approach begins when first you see the world through the eyes of another." This famous quote from Charles Churchman illustrates the need for us to be able to overcome our self centered view of the world if we wish to become systems thinkers and better understand complex systems.

A greater understanding of complex systems can not be realized through gaining more expertise from one perspective but can only increase through the synthesis of multiple perspectives. From including more aspects we can move away form an eco-systems perspective to an “ecosystems" view of the world where we are able to better understand ourselves as part of many complex adaptive systems

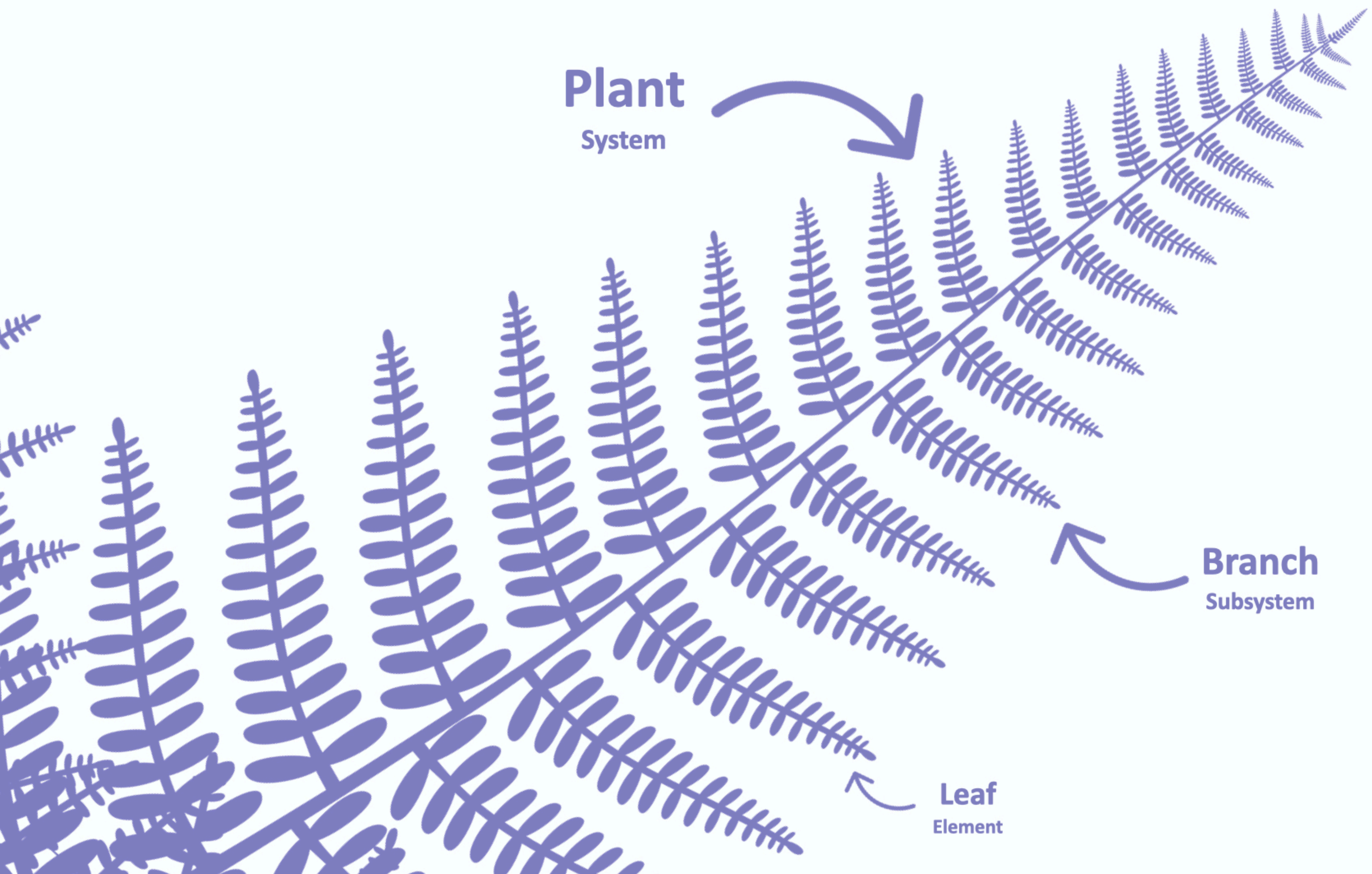


Principle
4

Dimensionality

Multi-dimensionality refers to the nature of systems having multiple different patterns of organization across space and time horizons that form different paradigms. Working with complexity requires that we recognize these different frames of reference and their diversity.

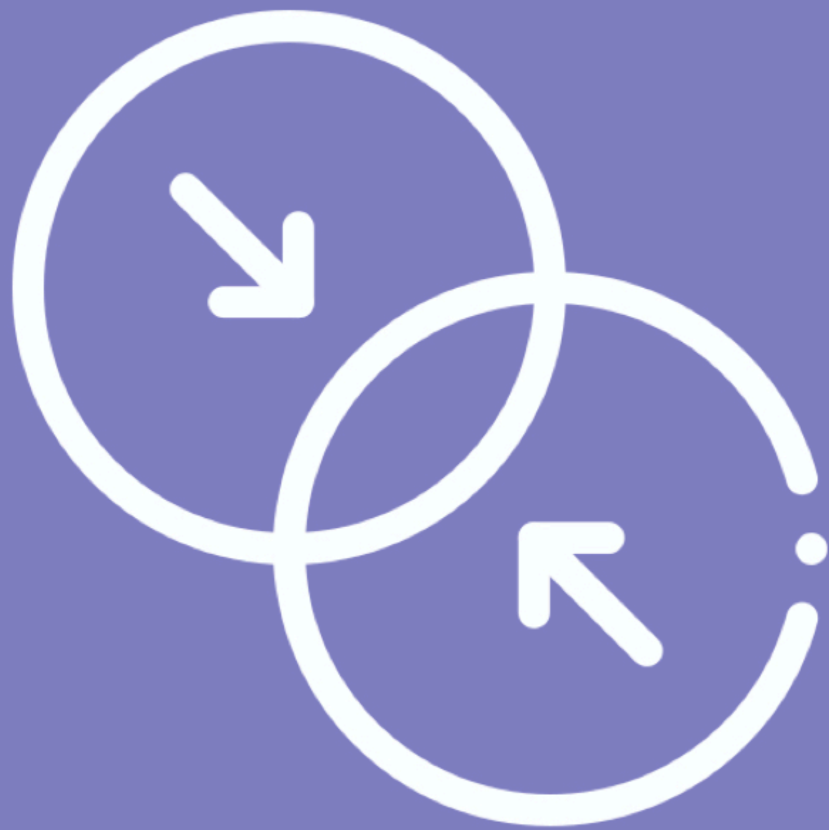
While reductionism aims to reduce an account of reality down to a single dimension, systems approaches embrace the multi-dimensional nature of complex systems both in space and time. Systems thinking considers relationships among levels and their ordering according to emergent processes that form nested, multi-leveled structures. This emergent, nested structure can be found in virtually all complex systems such as patterns of governance where local administrations are nested within regions, nation, and global forms.



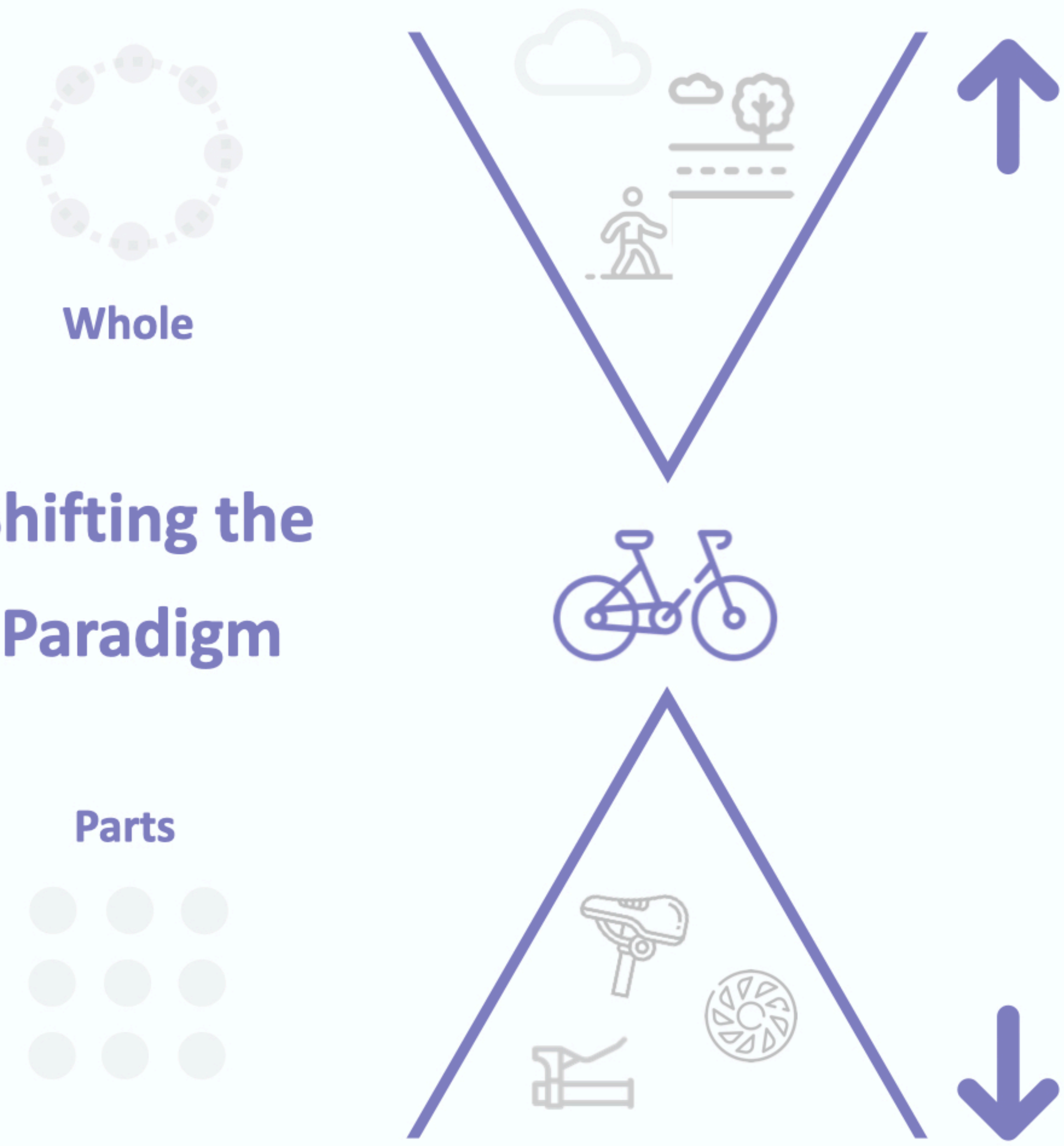
Principle
5

Synthesis

Synthesis means the combination of components or elements to form a connected whole. Synthetic thinking looks at the way the elements of a system are combined to form the functioning entirety. As opposed to analysis which breaks things down, this is a mode of thinking that reasons upwards to see what emerges when we put elements together. Synthetic thinking helps us to better understand emergent processes and the purpose of a system within its context.



The first step in the process is to identify the system that our object of interest is a part of. Next, we try to gain a broad outline of how this whole system functions. Lastly, we try to understand how the parts are interconnected and arranged to function as an entirety. By completing this process we can identify the complexity of relations within which our entity is embedded, its place and function within the whole.



Synthetic Thinking

Synthesizes parts to understand them with reference to the broader systems they form part of.

Is good for...

Understanding the “why"
Understanding context
Improving systems coordination
Transformational Change

Analytical Thinking

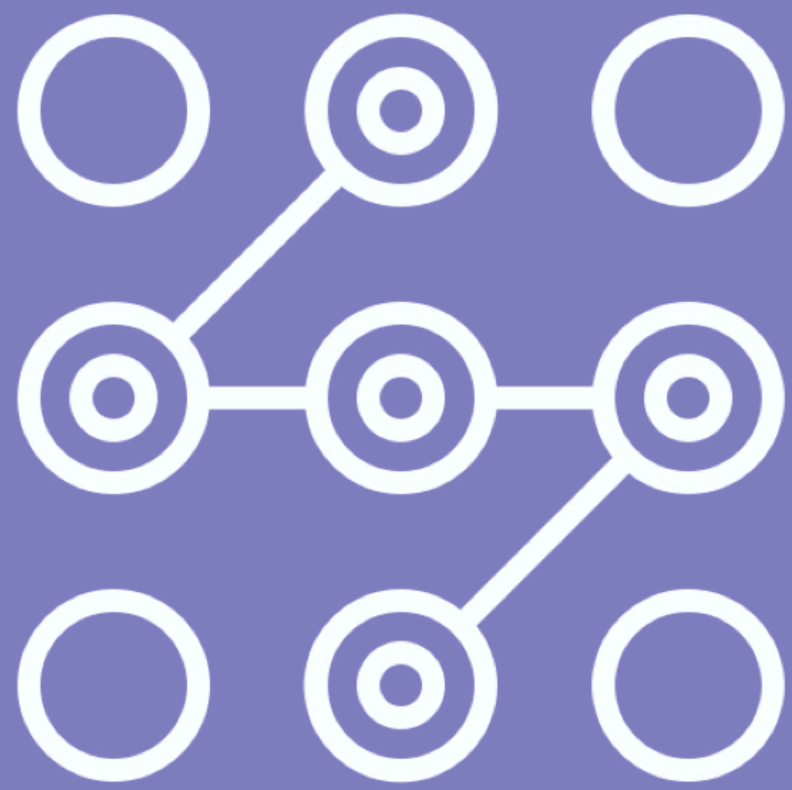
Reduces down to create an account of the whole with reference to the combination of more basic building blocks.

Is good for...

Understanding the “how"
Understanding internal workings
Increasing efficiency of parts
incremental improvements

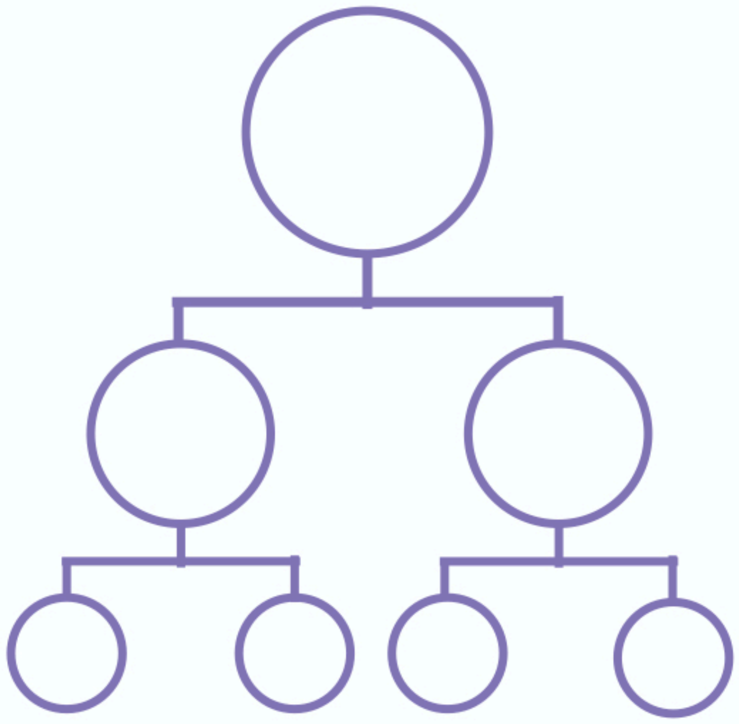
Emergence

Emergence is a term used in philosophy, art, and science to describe how new properties and features are created as we put things together. Emergence describes a process whereby component parts interact to form synergies, these synergies then add value to the combined organization which gives rise to the emergence of a new macro-level.



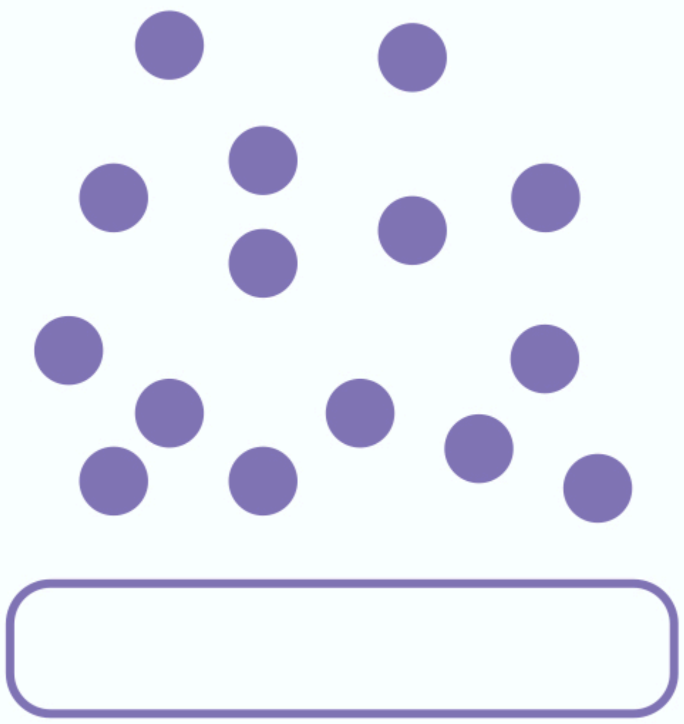
Because emergent properties are a product of the synergies between the parts, they cannot be observed locally in the subsystems, but only as a global structure or integrated network. In such a way emergence creates a system with two or more distinct and irreducible patterns of organization called integrative levels. Examples of emergent processes include the formation of hurricanes, social movements, traffic jams, and the flocking of birds or schooling of fish.

Emergent Thinking



Reductionism

Reductionism works to break systems down in to parts within hierarchical structures thus removing the possibility for understanding emergence



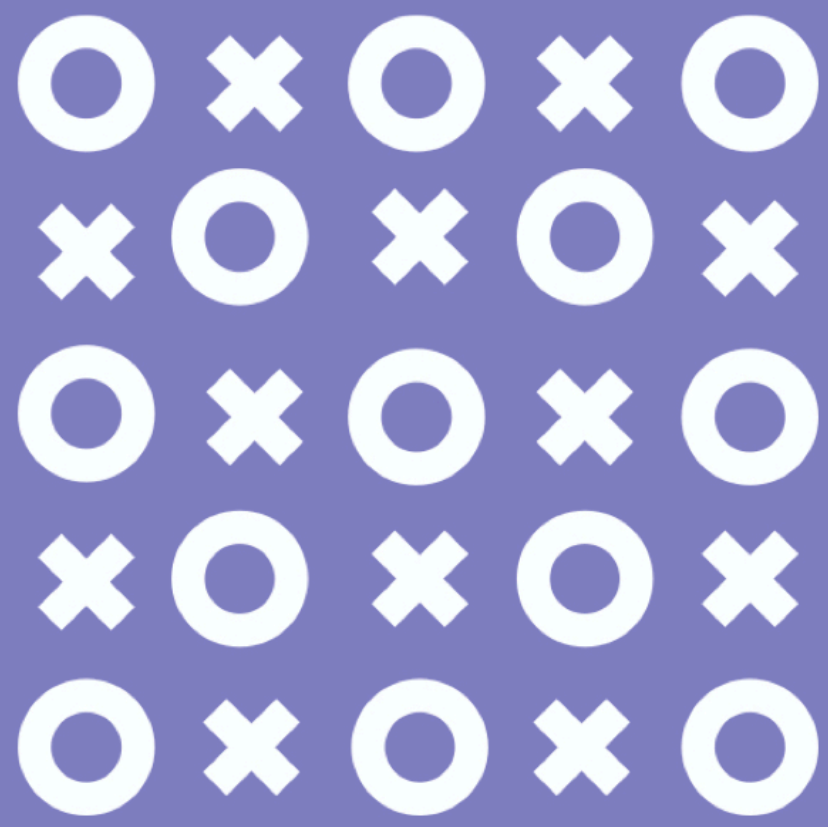
Emergence

Systems thinking looks at how small parts come together in a bottom-up way and thus helps us to better understand emergent patterns.

Principle
7

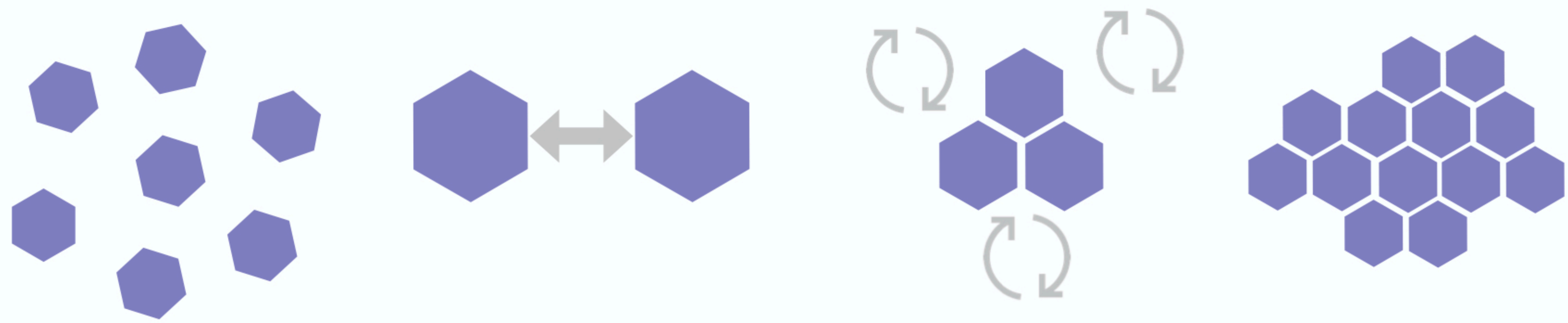
Self-organization

Self-organization describes how global patterns of organization within a system can emerge out of the local interactions between the components without global centralized coordination. The theory of self-organization seeks a description of how order emerges in a system through the interaction between the elementary parts in a bottom-up fashion.



The process of self-organization can be seen to work through nonlinear interactions between elements that are amplified by positive feedback loops to create attractors that close in on themselves resulting in a new pattern of organization emerging on the macro-level. Examples of self-organizing processes include the swarming of bees, chemical processes of crystallization, the formation of black markets or the creation of cultures or new languages.

Self-Organization - How it Works



Initial Disorder

Self-organization can only take place in the absence of a fixed global pattern

Peer Interaction

Component parts interact & some elements come to synchronize their states

Feedback

As coordination results in more efficient outcomes it creates a positive feedback dynamic

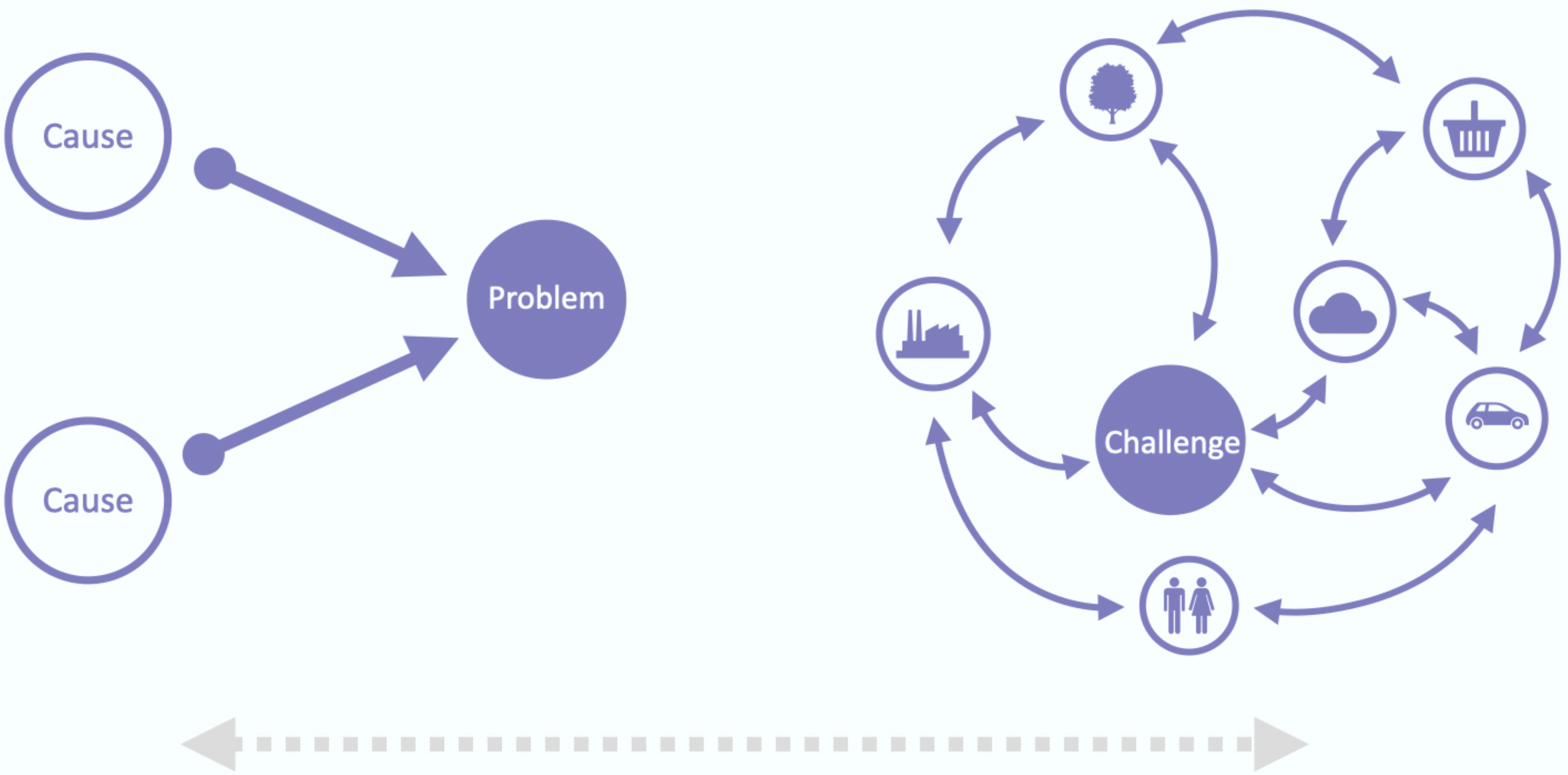
Attractors

Positive feedback creates explosive growth bringing parts into an emergent pattern

Nonlinearity

Nonlinearity describes a relationship where there is no direct linear connection between two variables, but instead changes can only be ascribe to multiple indirect connections or feedback dynamics. Nonlinearity allows for the output of an interaction to be more, or less, than the sum of the parts in isolation making nonlinear systems non-additive.

Nonlinearity is the product of the synergies between parts which makes their combined effect different from the parts taken separately. For example, due to the specific interactions within a drug concoction the combined effect of the drugs is different from each being taken separately. Because of the feedback loops between parts the output to a nonlinear system may be disproportionate to the input and they may grow or decay at an exponential rate. As can be seen in a financial crisis due to the positive feedback loops between the actions of the agents.



Linear Thinking

Reduce down to the most immediate and largest causes of the issue

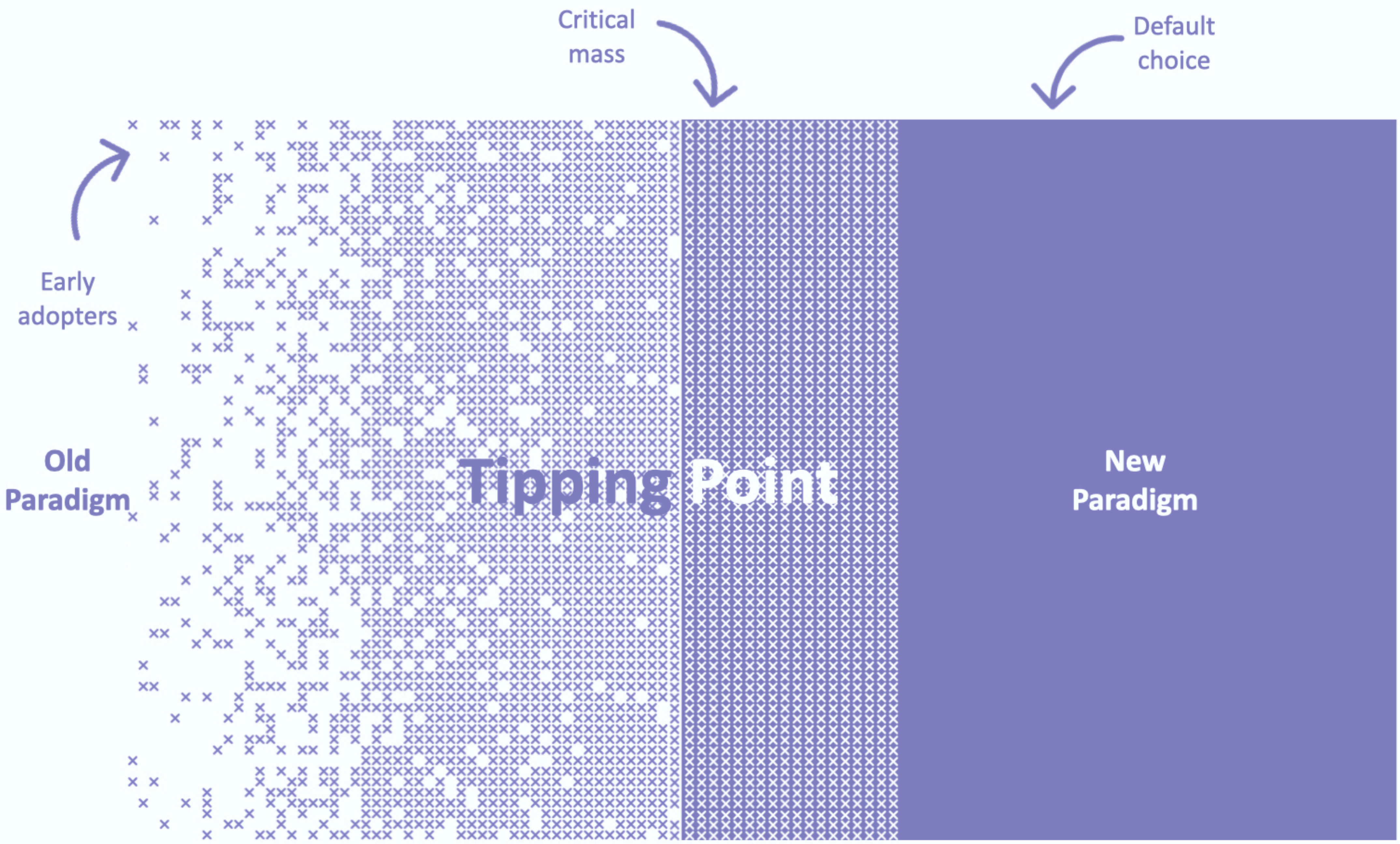
Nonlinear Thinking

Look at the network of factors that are creating the system's dynamics out of which the issue emerges

Phase Transition

A phase transition is a qualitative change in the overall structure and conditions of a system as it transitions from one regime to another. During a transition the global structures that supported the system previously disintegrate and new ones have to emerge - this makes transitions inherently unstable periods marked by nonlinearity.

Phase transitions are inherently nonlinear processes involving periods of exponential change. The transition of ice to steam is one example of a phase transition. At some critical temperature, a small change in the system's input temperature value results in a systemic change in the substance after which it is governed by a new set of parameters and properties. For example, we can talk about cracking ice but not water. Phase transitions can be seen in all kinds of complex systems, such as a political transition from monarchy to democracy.

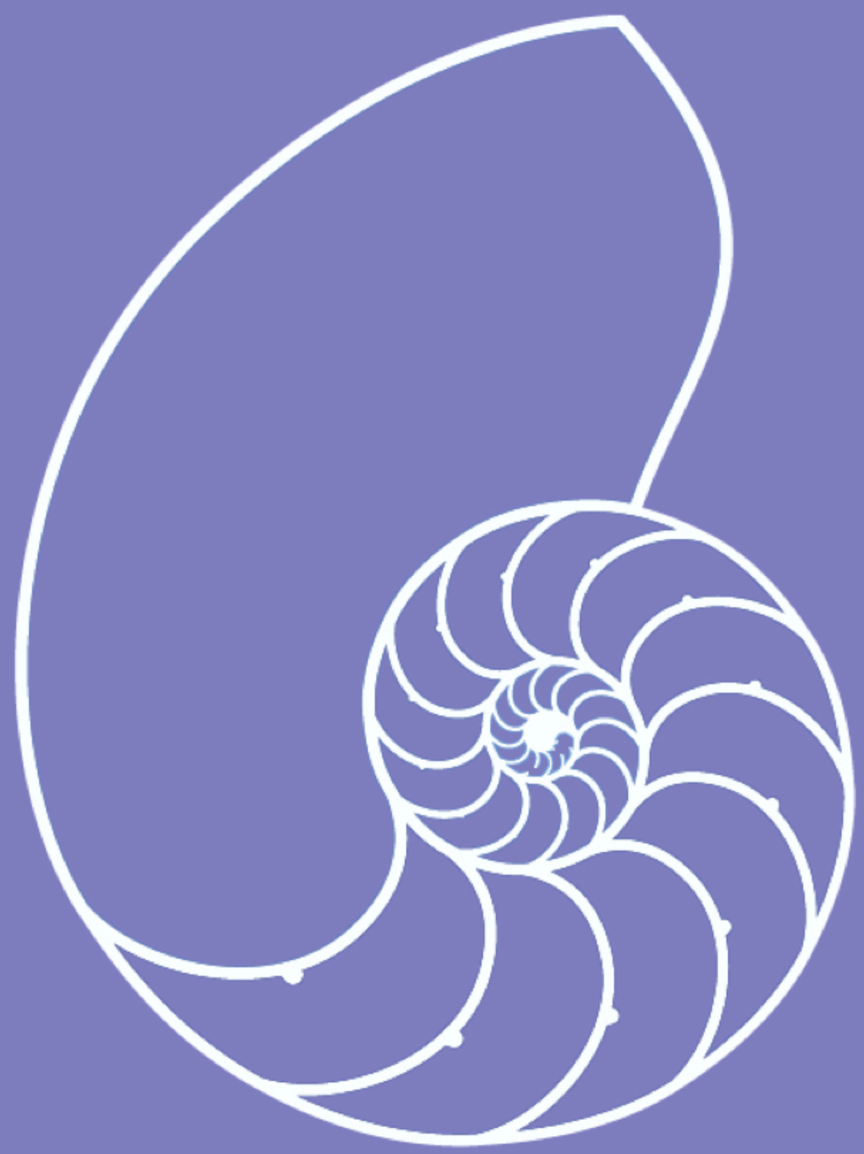


Principle 10

Integrative Levels

An integrative level is a pattern of organization emerging on pre-existing phenomena of a lower level. Typical examples include life emerging out of non-living substances, and consciousness emerging out of the nervous system or social institutions emerging out of individual people interacting.

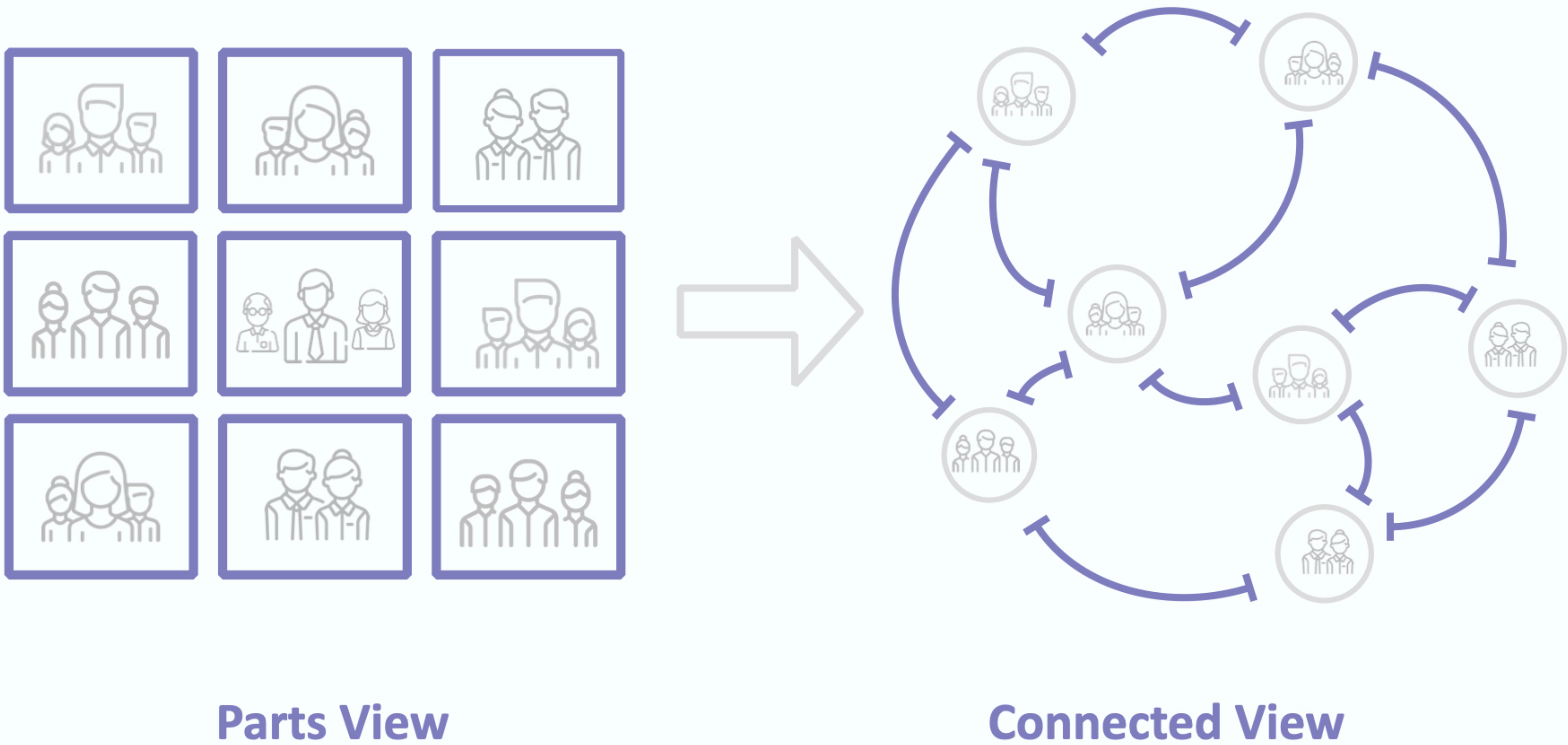
As components combine to produce larger functional wholes in hierarchical series, new properties emerge, and one cannot explain all of the properties at one level from an understanding of the components at the level below. The idea of integrative levels is central to the theory of emergence as integrative levels can be understood as the product of the process of emergence having played out to generate two or more qualitatively different levels of organization.



Connectivity

Relational thinking is a way of seeing the world that places greater precedence on the relations or connections between entities rather than simply looking at those elements as separate. The main overarching principle in the relational paradigm is a shift in one's perception from seeing a fixed world, made up of things and their properties, to seeing a world that is primarily made of relations and connectivity.

Going from a system with a low degree of connectivity to one with a high degree of connectivity is not just a quantitative change in the number of connections it is also a qualitative change. It marks a shift from a component based regime, where we need to firstly think about the properties of the elements in the system and their linear interactions - to a relational based regime where we need to first look at how the system is interconnected and the nature of the interdependencies.



Principle 12

Interdependence

Interdependence is a type of connection or relation between elements. Relations may be defined as either dependent, co-dependent, independent or interdependent. Interdependent means an interrelationship between autonomous elements through the formation of a combined, emergent organization. Interdependency is a central concept used to define a system and complexity, in that without interdependency between parts there is no system - just a set of independent elements.

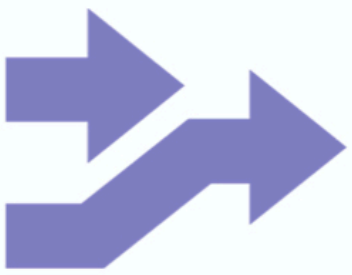
The essence of interdependence involves autonomy, differentiation, and emergence. Two or more autonomous elements coming together, differentiating their states with respect to each other, to create some combined organization that is greater than any of the parts, through the process of emergence. An example of this includes the interdependencies created in forming a family as well as most forms of social organization.

Emergent Interdependent Whole

Synergies

The term synergy comes from the word working together. A synergy is an interaction between two or more things that combine to create an effect that is different in some way from the two combined effects acting in isolation. Synergy is a prevalent phenomena in all types of systems that arises from the concerted action of multiple factors producing an amplification or cancellation effect compared with individual actions alone.

A positive synergy is when two things combine in a constructive fashion arising when the parts are both different from each other but also uniquely fitting together. Examples being the pollination process between bee and flower, or two companies working together that have different but complementary capacities. A negative synergy is a form of interference. Two people talking at the same time is a form of negative synergy.

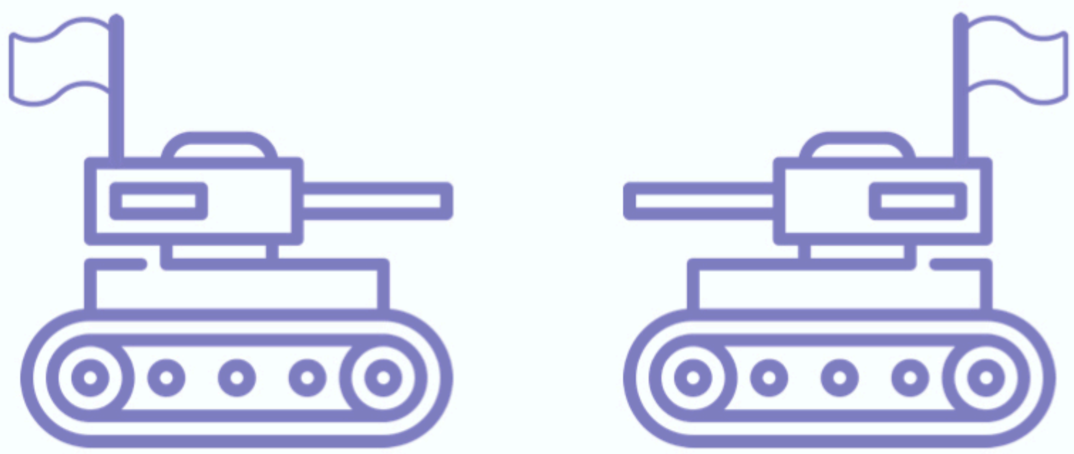


Positive Synergy

Parts are working in a constructive fashion to create a new organization with greater functional capacities e.g. the interaction between be and flower during pollination.

Negative Synergy

Parts work in a counteractive fashion to dampen down or destroy the effects of each other e.g. an arms race between two countries.

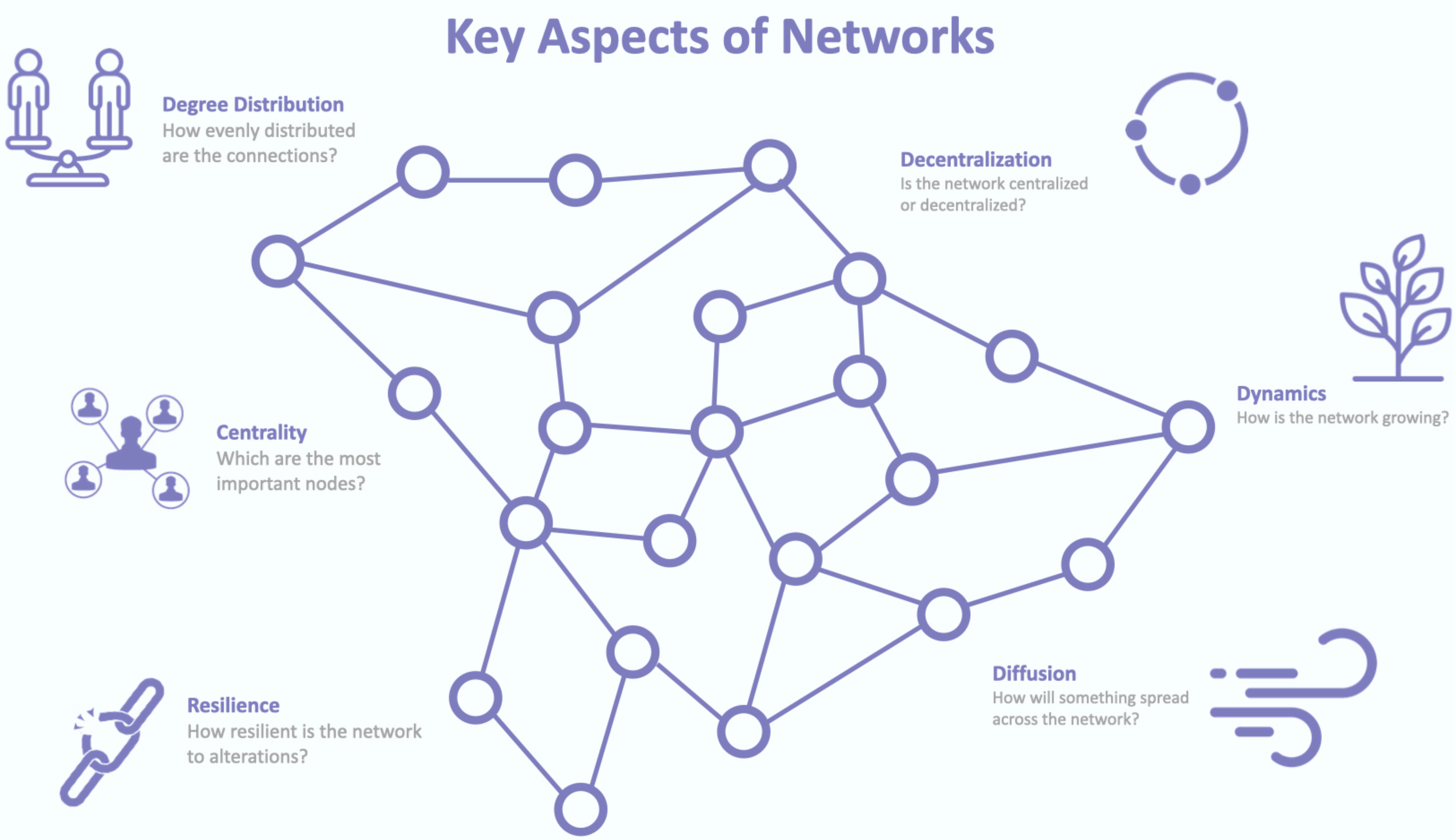


Principle
14

Networks

Due to their high level of connectivity, all complex systems have a network architecture to them and it is a defining feature of how they work. Thus network theory is central to understanding complex systems of all kinds, be that the Internet, a transport system, or a social network.

When attempting to understand a network there are a few key considerations. Firstly how connected are the elements in the system? Are there connections between all the parts or are some parts disconnected and separate from others? How dense is this set of connections? What are the patterns of clustering within the system? Is the network more centralized or decentralized? How robust is it to the failure of some nodes or connections? How might something spread across the network? Answering these will help us gain a deeper understanding of the workings of a system.



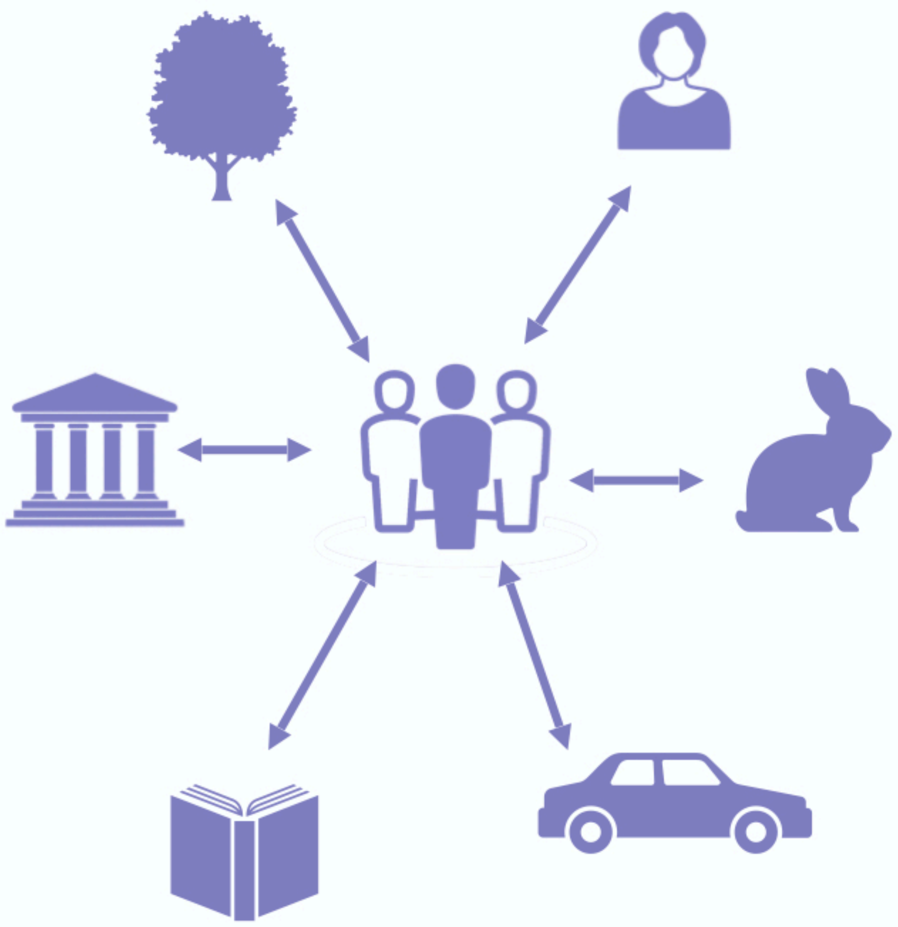
Decentralization

Decentralization is a structural feature of a network that has an even distribution of nodes and connectivity such that there are no elements with a radically higher level of connectivity and capacity that would make them central to the network. Examples include grid computing, social movements, or peer-to-peer file-sharing networks.

Decentralized networks have unique characteristics that differentiate them from centralized networks. Capacity and connectivity are more evenly distributed across the elements in the system. They are typically more adaptive and respond to local changes thus allowing for greater diversity of nodes. They have lower levels of dependency on key nodes making them less critical and potentially more resilient. With centralized nodes as super spreaders information often permeates more slowly across the network while alignment and coherence can be more difficult to achieve.

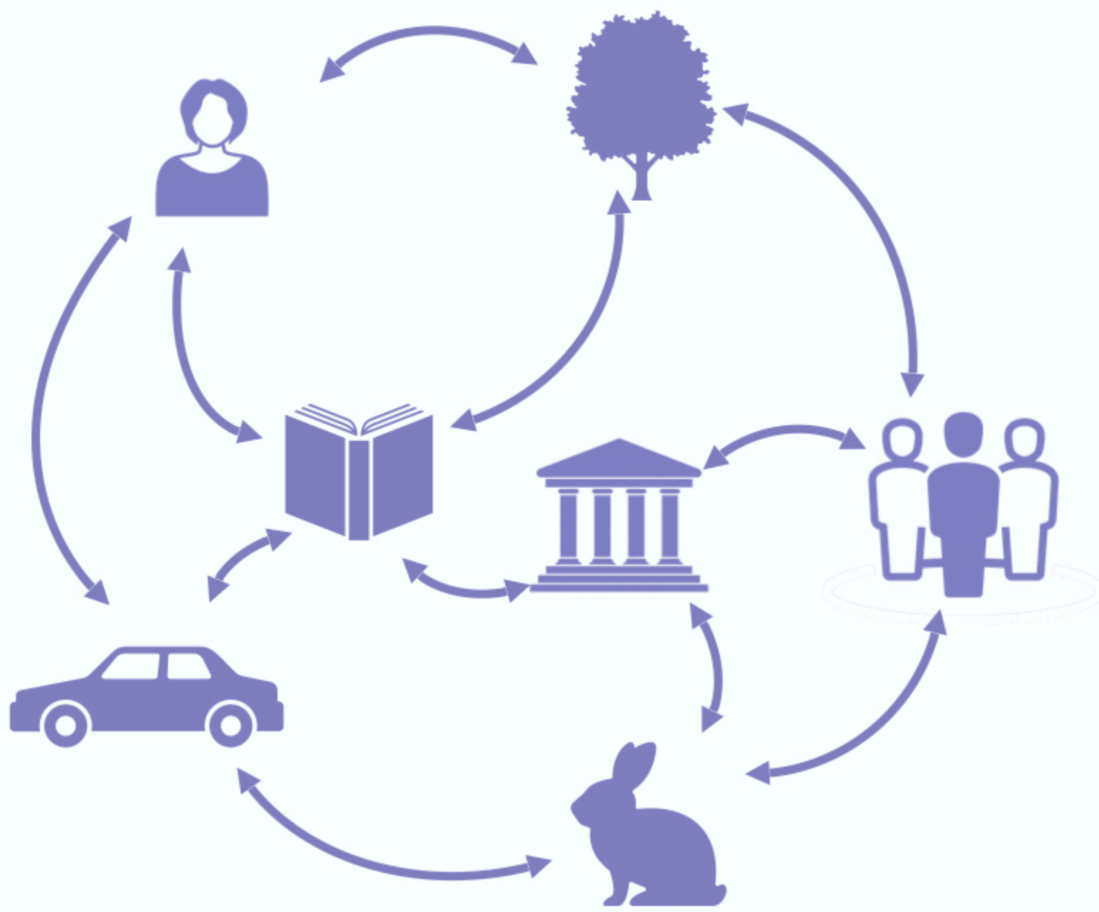
Centralized Network

Some elements have a very high number of connections



Decentralized Network

All elements have a relatively equal amount of connections



Adaptation

Adaptation is the capacity for a system to change its state in response to some change within its environment. An adaptive system is a system that can change given some external perturbation, and this is done in order to improve or maintain its condition within an environment by modifying its state.

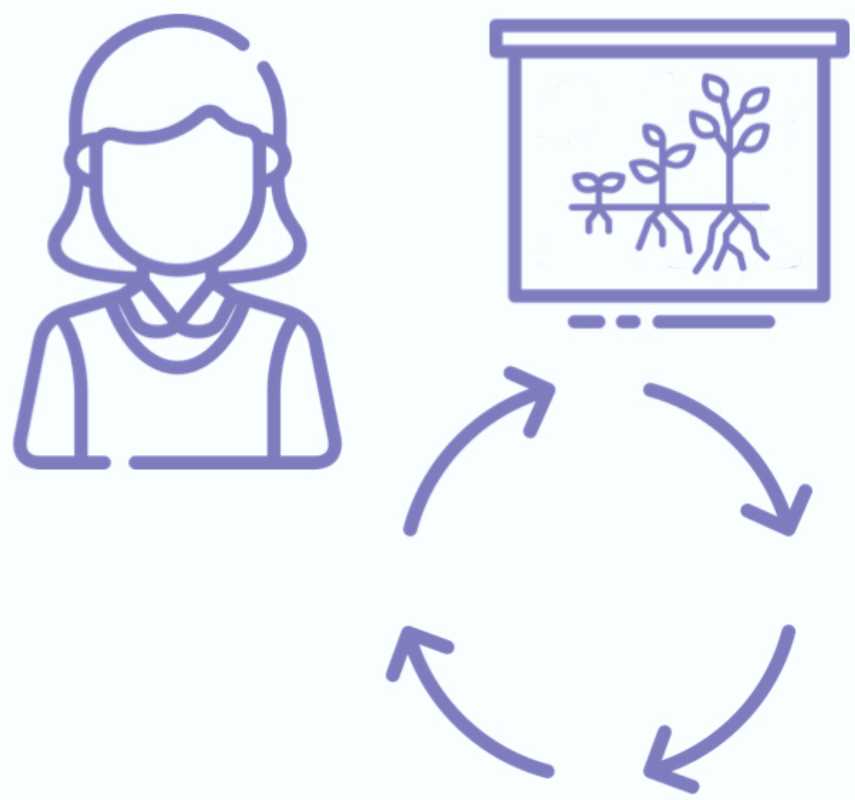
Complex adaptive systems are all around us from financial markets to ecosystems to the human immune system. These systems consist of many actors that are acting, reacting, and adapting to each other's behavior, out of this often chaotic set of interactions emerges global patterns of organization in a dynamic world of constant change and evolution where little is fixed & determined.

Fixed Planning Approach

Plan out a change process through analysis, design and control the parts towards a pre-specified desired state.

Iterative & Adaptive Approach

Set the conditions for iteration based upon simple rules to grow the change.

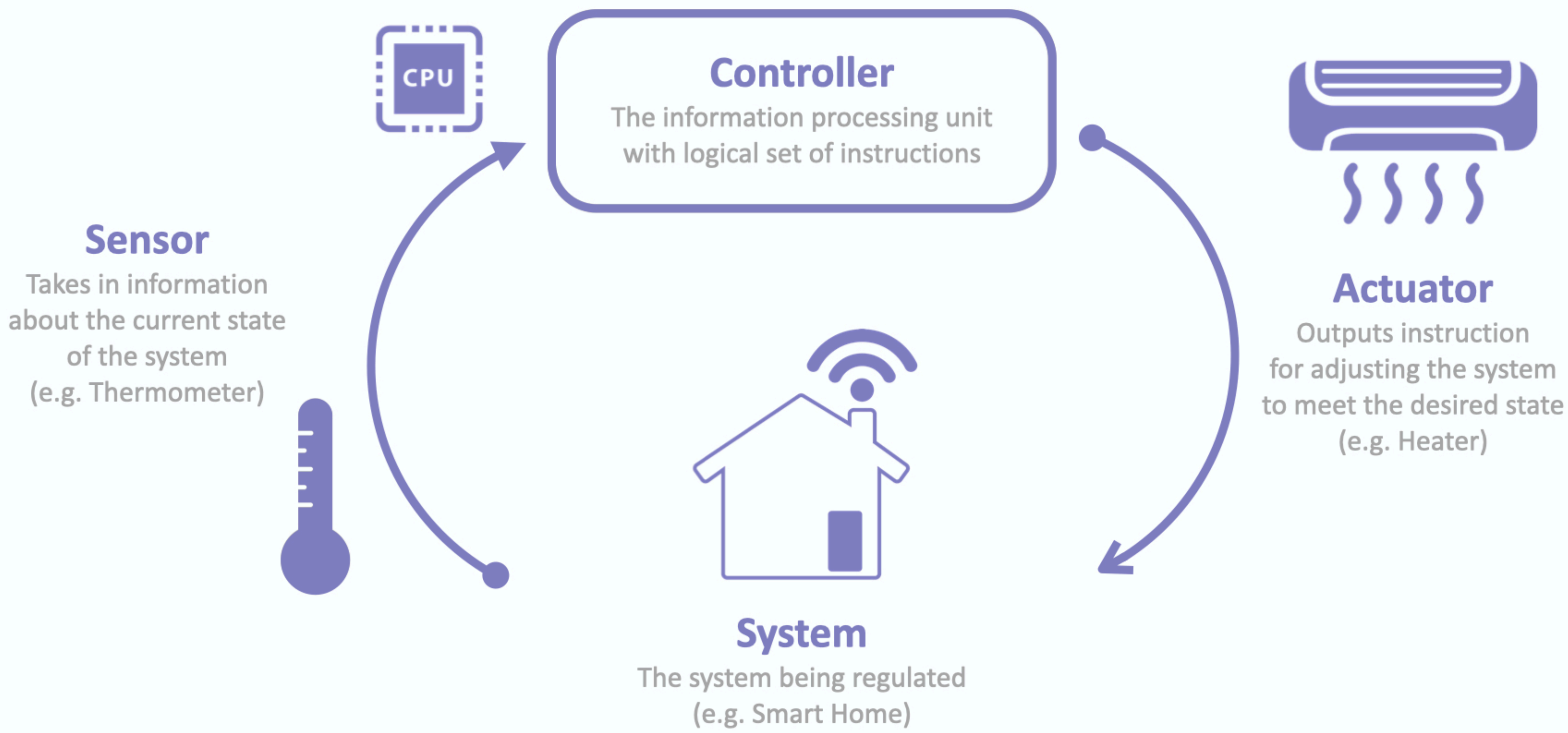


Cybernetics

Cybernetics is the study of control, communications and information processing within systems of all kind, biological, technological and social. The word cybernetics comes from the Greek word meaning “governance” or “to steer, navigate or govern”. Cybernetic systems use information and communications processes to guide a system in the direction of the set of environmental parameters that are best suited for maintenance homeostasis and functionality.

The primary object of study within cybernetics are control systems that are regulated by feedback loops. Feedback loops are a fundamental object of study within cybernetics in that they are accountable for the process of regulation within all control systems. Examples of cybernetic systems include the regulatory units to chemical processing plants, the human body, governments, etc.

How Cybernetic Systems Work



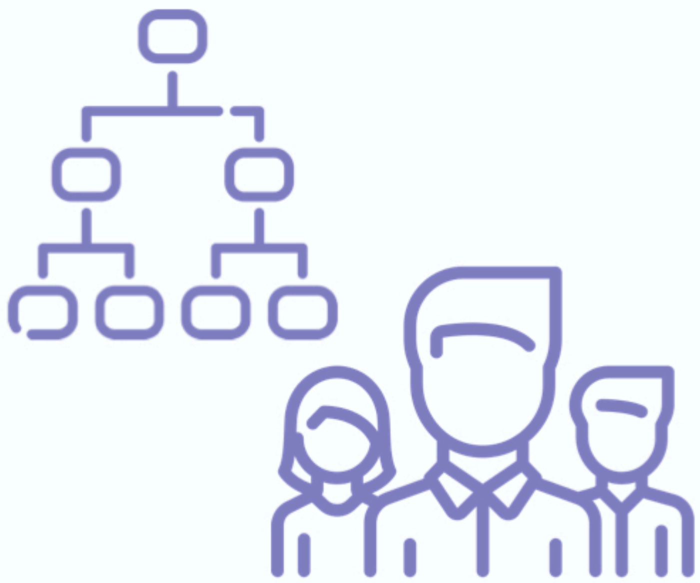
Game Theory

Game theory is the formal study of situations of interdependence between adaptive agents and the dynamics of cooperation and competition that emerge out of this. A game is a system wherein actors are interdependent in affecting each other and the overall outcomes of the situation. Game theory attempts to understand the structure of these games' incentives to determine the likely or optimal actions of the actors.

Examples of games include the political negotiations between two nations, the interaction of businesses within a market, and the different strategies adopted by creatures in an ecosystem. An understanding of games, their structure and inherent incentives towards cooperation or competition can lead to an increased capacity to design and guide them towards cooperative outcomes.

Cooperative

Where everybody cooperates, resulting in everyone gaining



Noncooperative

Where members do not cooperate, resulting in suboptimal outcomes for many.

Degree of Cooperation

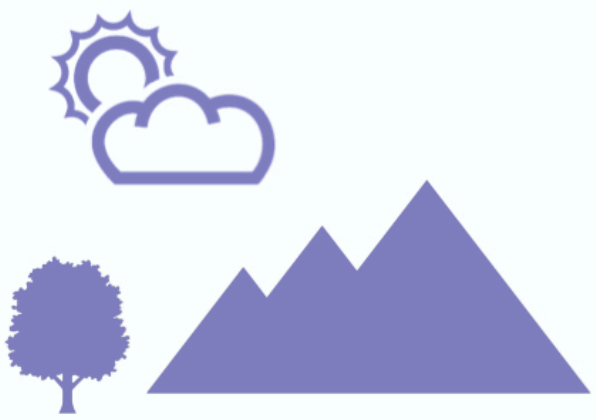
Depends upon people interacting with others they know within structures that enable people to give feedback with a transparent rating, reputation, and identity around their level of cooperation in the past.

Evolution

Evolution is the adaptation of a group of entities that occurs on a macro-level over a period of many life cycles reflecting the response of the collection of agents to changes in their environment. Evolution functions through a process of, variety production, interaction, selection, and replication which works to select those elements within a system that are best suited to their operating environment.

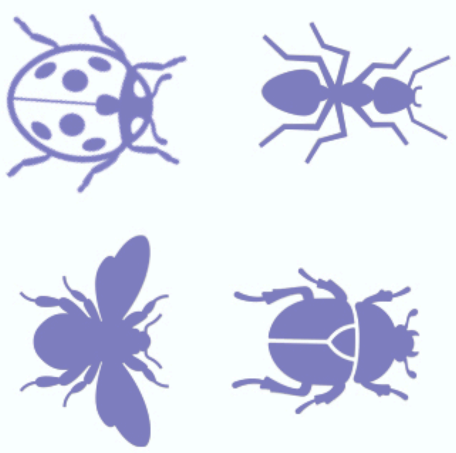
Through the iteration of this process of evolution over a prolonged period, a complex adaptive system can go from starting simple to becoming more complex. Although the idea of evolution is associated with ecosystems, complexity theory deals with the concept on a slightly more abstract level as it applies to all complex adaptive systems from the development of civilization to financial markets, cultures, and technologies.

Evolution - How it Works



1. Change

A population of agents exists within some environment and must periodically adapt as a whole in order to survive and maintain functionality.



2. Variety

Responding to changes means selecting from a variety of different internal states or strategies, thus the need for diversity.

3. Selection

The different variants in the system are exposed to their operating environment to see which are best adapted and most successful within that context.

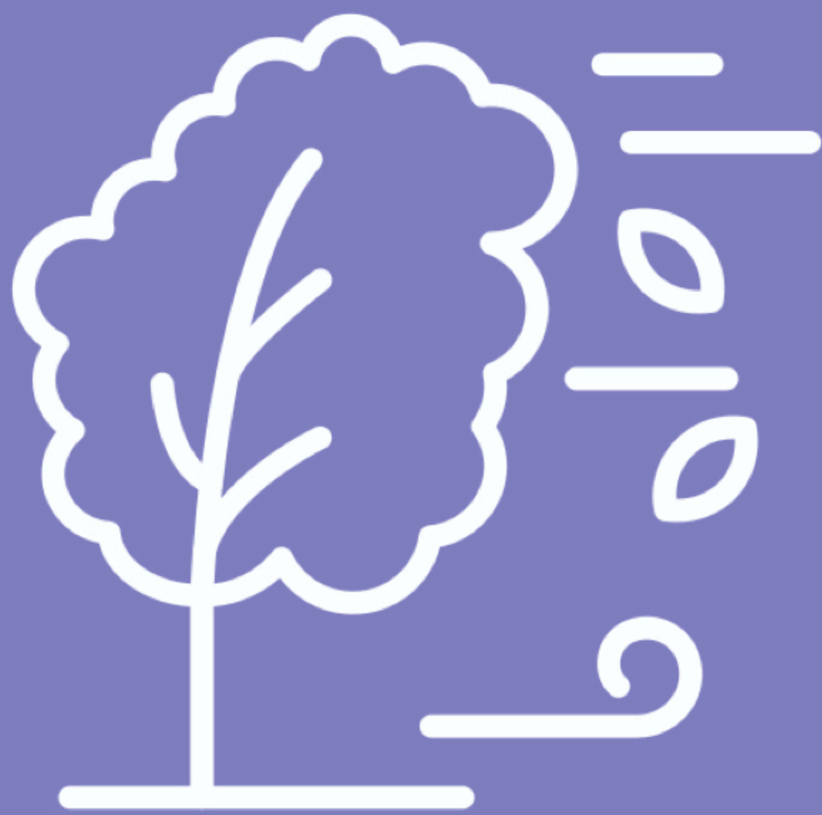
4. Replication

Those that prove "fittest" attract more resources and are duplicated, thus the system as a whole comes to express more of their characteristics.

Resilience

Resilience is the capacity of a system to maintain or restore functionality given some alteration. When a system is subject to a disturbance, it responds by moving away from its initial state. The tendency of a system to remain close to its equilibrium state, despite disturbances, is termed robustness. While the speed with which it adapts and finds a new viable state after disturbance may be understood as its resilience.

Resilience is a function of several different factors including the network's structure, dependency on input variables, diversity of components, etc. Resilience is built through a system's exposure to and survival of different changes within its environment. Forests become resilient to fires through experiencing and surviving periodic small forest fires. A child's immune system becomes resilient through exposure to foreign invaders and developing an appropriate response.

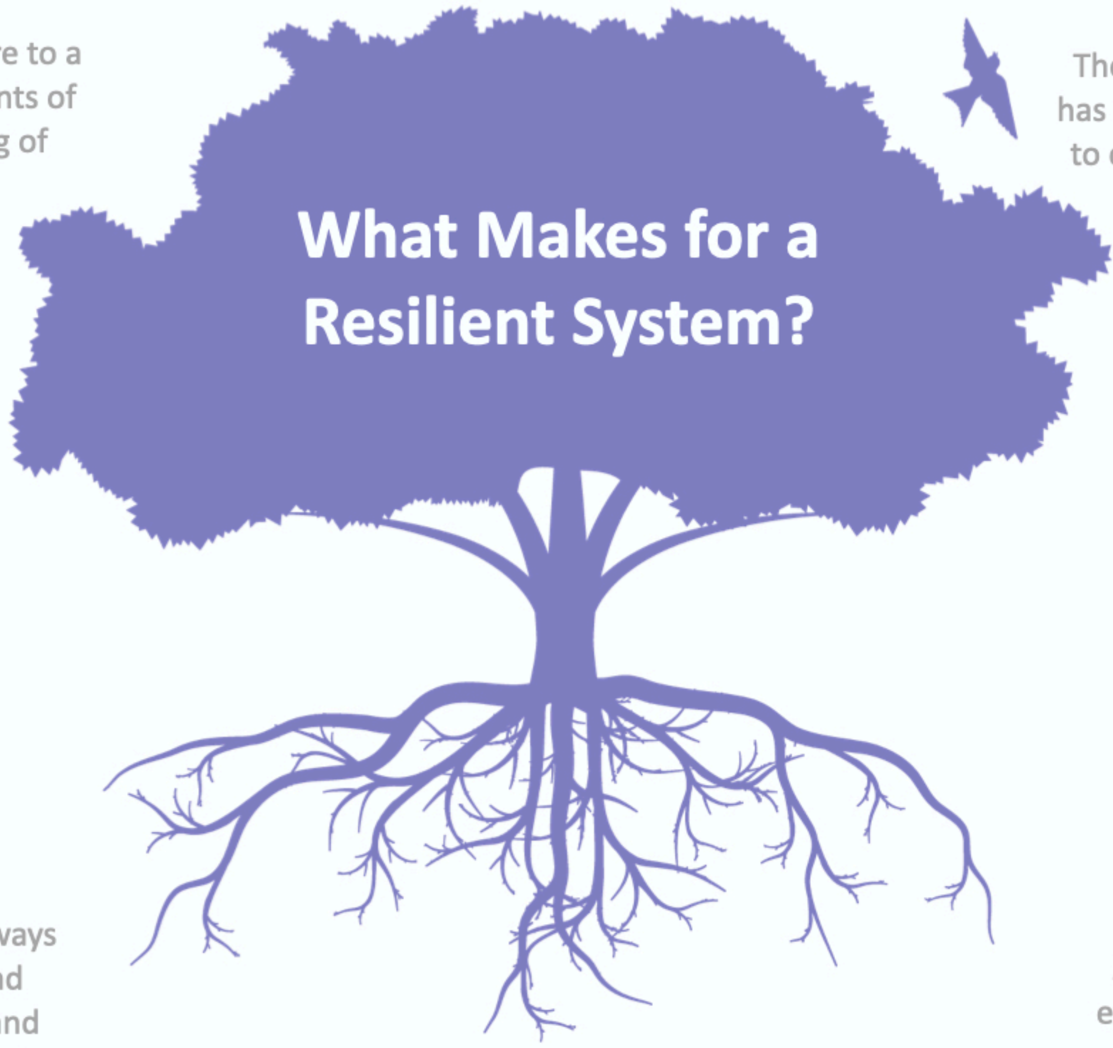


Decentralization

A decentralized network structure to a system creates fewer critical points of failure and slows the spreading of failure across the system.

Self-sufficiency

The fewer the dependencies the system has on inputs the fewer the vulnerabilities to change and the greater its capacity to adapt to a change successfully.



Variety

Variety creates more possible ways that the system could respond successfully to a given event and reduces the possibility of a given shock to cascade through the system.

Learning

Accumulated learning from having experience and successfully survived past challenges helps to build a systems adaptive capacity and resilience to future challenges.