Virtual Academy of Sustainability

Lecture 4: Systems Inquiry

Episode 2: Embracing Complexity

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Overview of the Lecture

Episode 1: Thinking in Systems

Episode 2: Embracing Complexity

Episode 3: Interview

Learning Outcomes

- You will learn the concept of complex adaptive systems and their relevance to the study of social-ecological systems.
- You will know the attributes of complex adaptive systems.
- You will understand a general concept of adaptive change.

Structure of Episode 2

1. Defining Complex Adaptive Systems
2. Complex Adaptive Systems Attributes
3. Cycles of Adaptive Change
4. Conclusion

Complex Adaptive Systems (CAS)

- Studying SESs as complex adaptive systems is a fast growing interdisciplinary field.

- The term *complex adaptive systems* (CAS) was coined at the interdisciplinary Santa Fe Institute (SFI), by John Holland, Murray Gell-Mann and others in mid-1980s.

- *Complex adaptive systems* are special cases of complex systems (systems exhibiting one or more properties not obvious from the properties of the individual parts).

  - They are "*complex*" in that they are diverse and made up of multiple interconnected elements.
  - They are "*adaptive"* in that they have the capacity to change and learn from experience (*self-organize*).

Complex Adaptive Systems (CAS)

- Most things we take for granted are complex adaptive systems.
- The brain, the immune system, the cell, the developing embryo.
- The stock market, ant colonies, ecosystems, the ecosphere (Gaia).
- Any human social group such as communities, institutions, political parties, etc.

CAS Attributes

- Complex adaptive systems have important attributes
- Non-linearity - small changes in the initial conditions of the system can have significant effects (often referred to as the *butterfly effect*)
- A rolling snowball for example gains on each roll much more snow than it did on the previous roll and very soon a fist sized snowball becomes a giant one.

Source: http://www.flickr.com/photos/redjar/113026147/ by redjar

CAS Attributes

- **Emergence** – the way unique and novel qualities emerge through the evolution of increasingly complex organizational patterns and processes.

- The emergent is unlike its components insofar as it cannot be reduced to the lower levels.

- The emergent property represent a new level of the system's evolution.

CAS Attributes

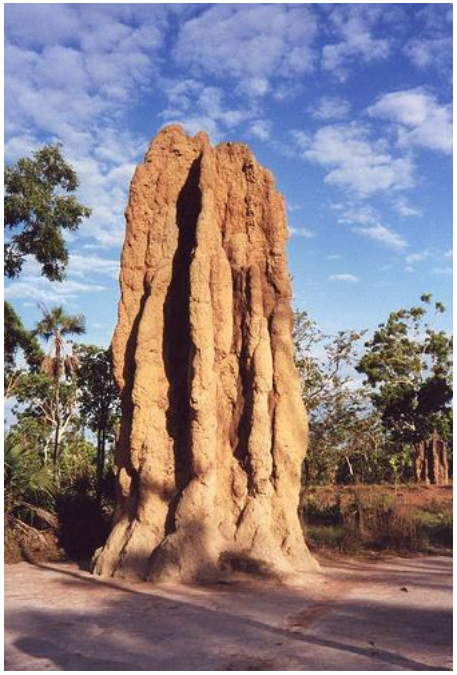
- An **emergent behavior or property** can appear when individual entities (agents) operate in an environment, forming more complex behaviors as a collective.

- The emergent phenomenon is not a property of any single entity, nor can it be predicted or deduced from behavior in the lower-level entities.

- If emergence happens over disparate size scales, then the reason is usually a causal relation across different scales.

CAS Attributes

- Emergent structures can be found in many natural phenomena, from the physical to the biological domain.
- The shape of weather patterns such as hurricanes are emergent structures.
- Termite hills – wondrous pieces of architecture with mazes of interconnecting passages, large caverns and ventilation tunnels are also emergent structures.



Source: http://www.flickr.com/photos/melfoody/5066261176/ by melfoody

CAS Attributes

- **Self-Organization** - is a process where some form of global order or coordination arises out of the local interactions between the components of a system

- This process is spontaneous: it is not directed or controlled by any agent or subsystem inside or outside the system.

- However, the laws followed by the process and its initial conditions may have been chosen or caused by an agent.

CAS Attributes

- It is often triggered by random fluctuations that are amplified by positive feedback.
- The resulting organization is wholly decentralized or over all the components of the system.
- As such it is typically very robust and able to survive and self-repair substantial damage or perturbations.

Source: http://www.flickr.com/photos/the_farnsworths/4484316401/
by Stephen & Claire Farnsworth

CAS Attributes

- **Co-evolution -** all systems exist within their own environment and they are also part of that environment
- As their environment changes they need to change to ensure best fit.
- But because they are part of their environment, when they change, they change their environment, and as it has changed they need to change again, and so it goes on as a continuous process.

CAS Attributes

- **Requisite Variety -** the greater the variety (diversity) within the system the stronger it is.

- Ambiguity and paradox abound in CAS which use contradictions to create new possibilities to co-evolve with their environment.

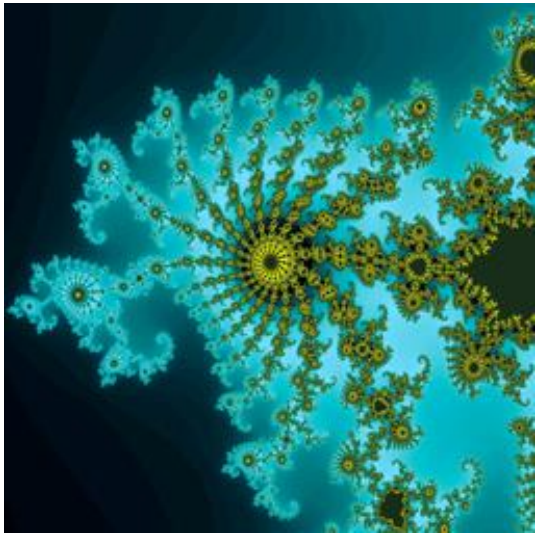
- Democracy is a good example in that its strength is derived from its tolerance and even insistence in a variety of political perspectives.

CAS Attributes

- **Connectivity** - the ways in which the agents in a system connect and relate to one another is critical to the survival of the system.

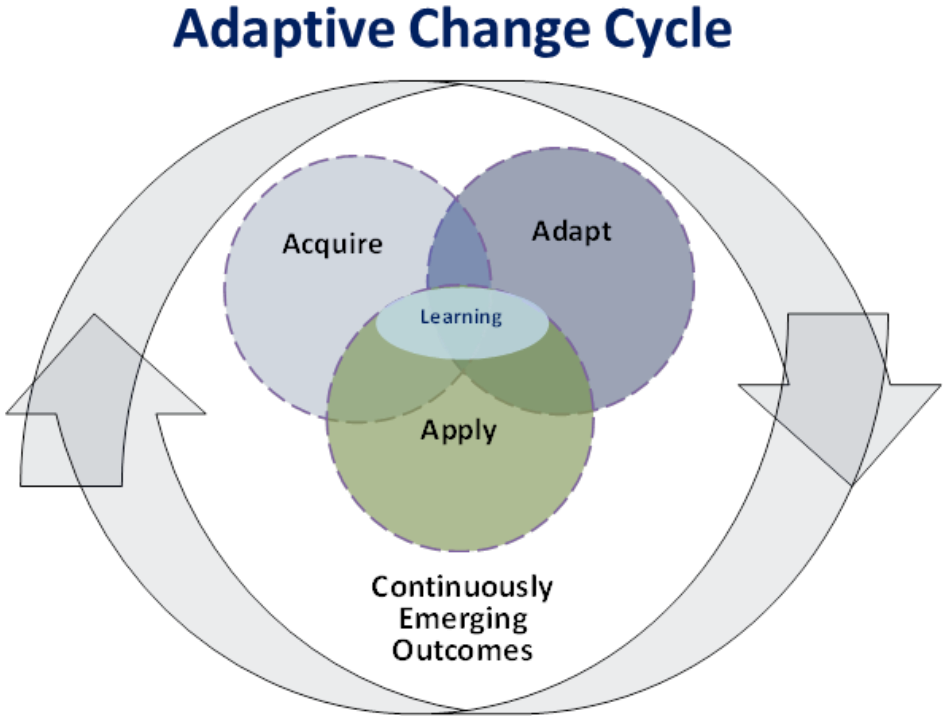
- Patterns are formed and feedback disseminated from these connections.

- The relationships between the agents are generally more important than the agents themselves.



Adaptive Cycle

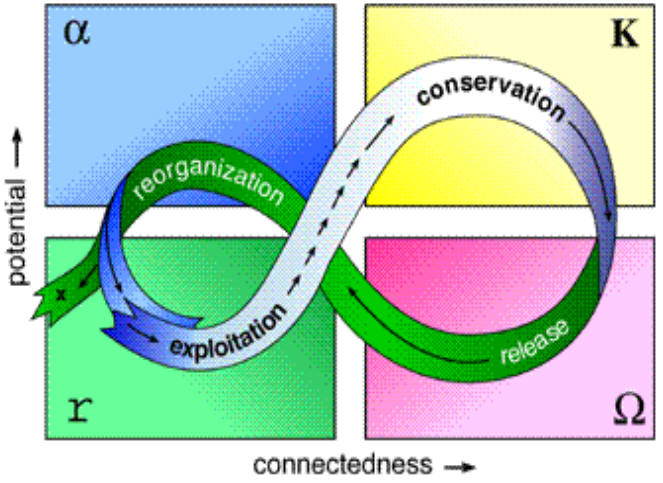
The adaptive cycle, originally conceptualized by C. S. Holling interprets the dynamics of human and natural systems in response to disturbance and change.



Source: http://thecomplexityspace.com/?p=1138

Adaptive Cycle

- In terms of its dynamics, the adaptive cycle has been described as moving slowly from exploitation (r) to conservation (K),
- maintaining and collapsing very rapidly from K to release (Ω), continuing rapidly to reorganization (α) and back to exploitation (r).

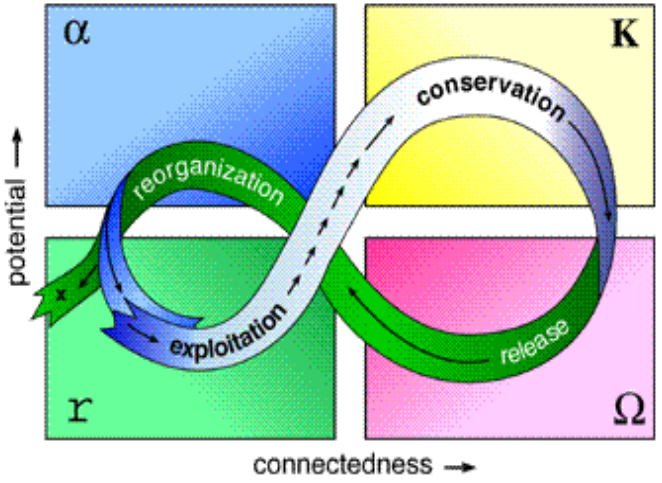


Source: Gunderson & Holling (2001)

Adaptive Cycle

Spruce-fir forests:

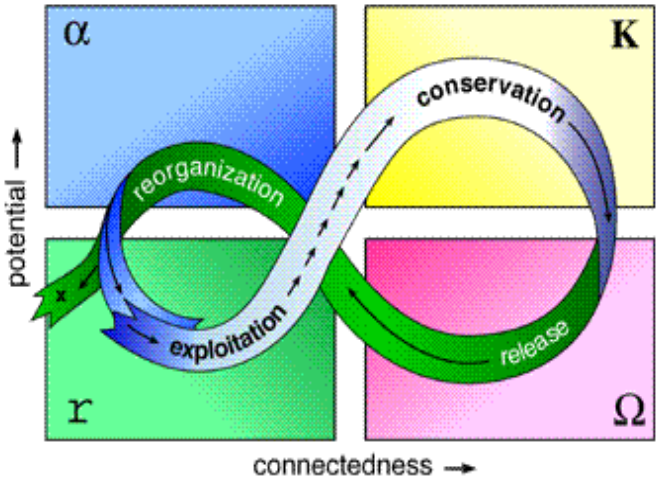
- Growth or exploitation (r) – early stages of ecological succession
- Conservation or accumulation (K) – "climax" community
- Collapse or release (Ω) – Forest fire or pest outbreak
- Reorganization or renewal (α) – soil processes make nutrients available for exploitation



Source: Gunderson & Holling (2001)

Adaptive Cycle

- The two main dimension that determine changes in an adaptive cycle are connectedness and potential.
- The connectedness dimension (horizontal axis) stands for a systems ability to internally control its own destiny.
- It "reflects the strength of internal connections that mediate and regulate the influences between inside processes and the outside world".
(Source: Gunderson & Holling 2001)

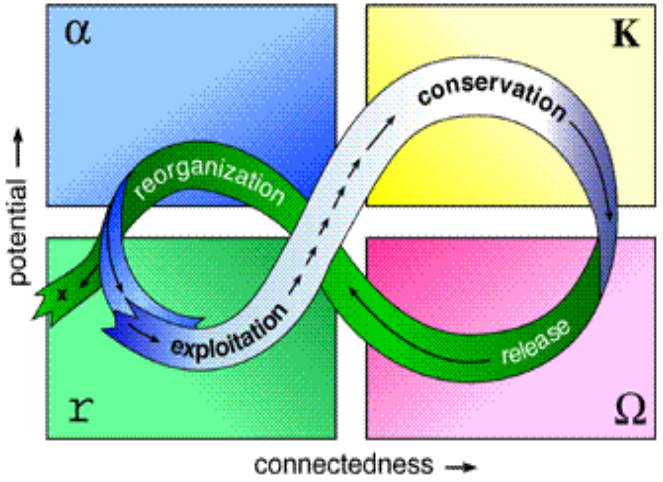


Source: Gunderson & Holling (2001)

Adaptive Cycle

- The potential dimension (vertical axis) stands for the "inherent potential of a system that is available for change".

- Social or cultural potential can be characterized by the "accumulated networks of relationships-friendship, mutual respect, and trust among people and between people and institutions of governance". (Source: Gunderson & Holling 2001)

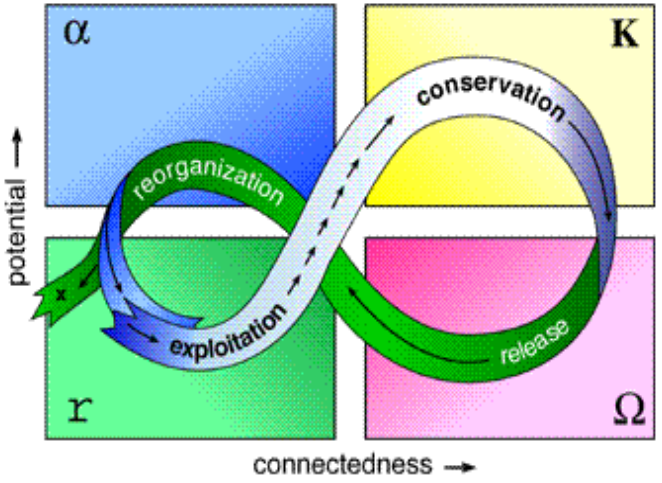


Source: Gunderson & Holling (2001)

Adaptive Cycle

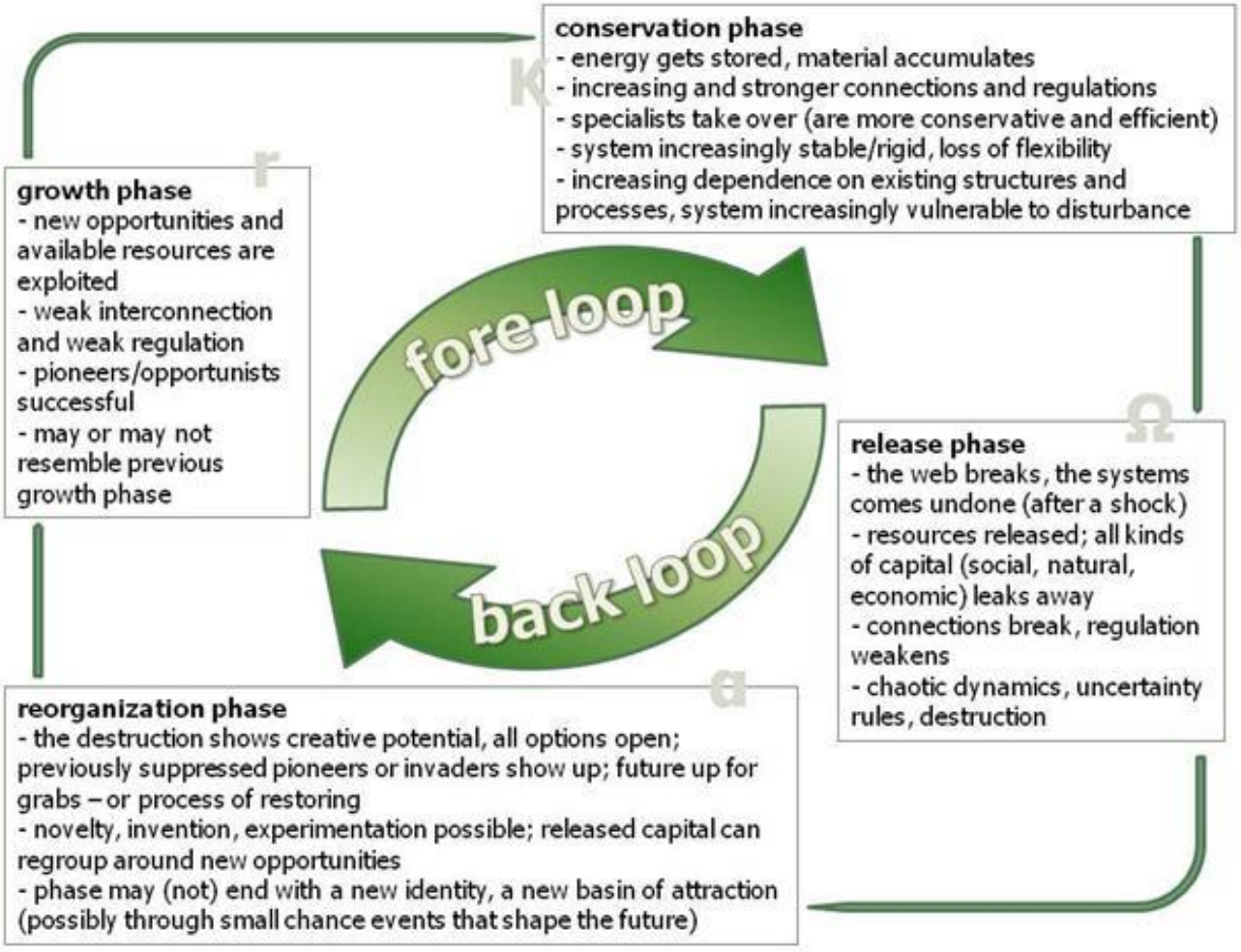
- According to the adaptive cycle concept, the levels of both dimensions differ during the course of the cycle along the four phases.

- The adaptive cycle thus predicts that the four phases of the cycle can be distinguished based on distinct combinations of high or low potential and connectedness.



Source: Gunderson & Holling (2001)

Adaptive Cycle



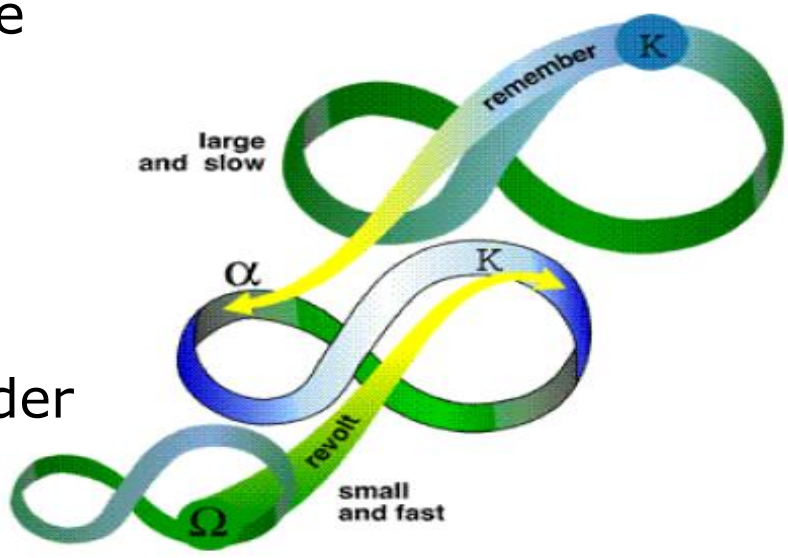
Source: http://www.responsiblebusiness.eu/display/rebwp2/Resilience+thinking

Adaptive Cycles

- Adaptive cycles are "*nested"* in a hierarchy across time and space, (panarchy) with integrated/over-lapping cycles of "*revolt*" and "*remember*".

- Smaller and faster levels invent, experiment and test; larger and slower levels provide the memory of the past to allow recovery.

- No system can be understood or managed by focusing on a single scale – it should consider at least three scales.



Source: Gunderson & Holling (2001)

Conclusion

- We live in a complex, dynamic world where everything is connected to everything else.

- We need better approaches to study, understand and manage complexity.

Conclusion

- Complex adaptive systems theory offers a powerful new approach to address complex social-ecological problems.
- Central to this approach is the idea that society and the environment that sustains us cannot be treated in isolation from each other.
- By understanding the broader context in which the challenges lie, we are able to identify sustainable solutions that, in turn, will lead to improved social-ecological health and adaptability.

Exercises for Self-Study

1. What does the shape and behavior of a flock of birds have in common with a school of fish and a swarm of bees?

2. What CAS attributes contribute to far-from-equilibrium states, unpredictability, and unforeseen sudden changes (surprise) in social-ecological systems?

3. What can panarchy ("nested" cycles of adaptive change) tell us about the future of modern industrial societies?

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