



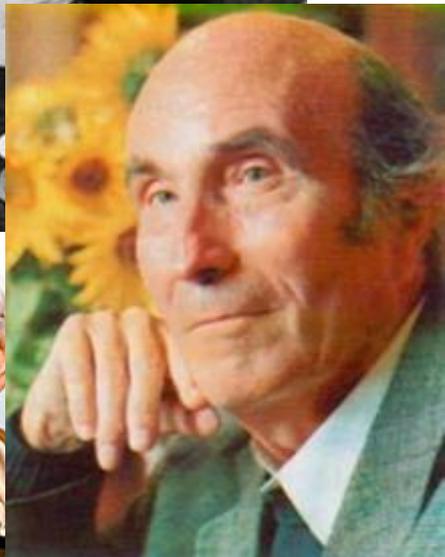
Sustainability of Complex Systems: Insights from ecological dynamics and systems thinking

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Systems Thinking Giants

a new paradigm

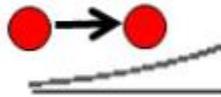
Many global environmental problems may soon be *irreversible* (e.g., extinction, soil loss, climate change).

These are *systemic problems* that cannot be understood in isolation but rather are interconnected and interdependent.

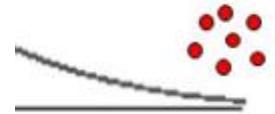
Solutions may be simple but will require a radical shift in our perceptions, our thinking, and our values.

The **ORDER** in Complexity

Changes our view of appropriate methods
degree of analysis from the simple and
complex



Simple
Causality
(Newton)



Dis-ordered
Complexity
(Statistics)



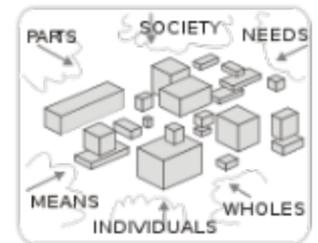
rise of systems thinking

– from parts to wholes:

systems thinking:

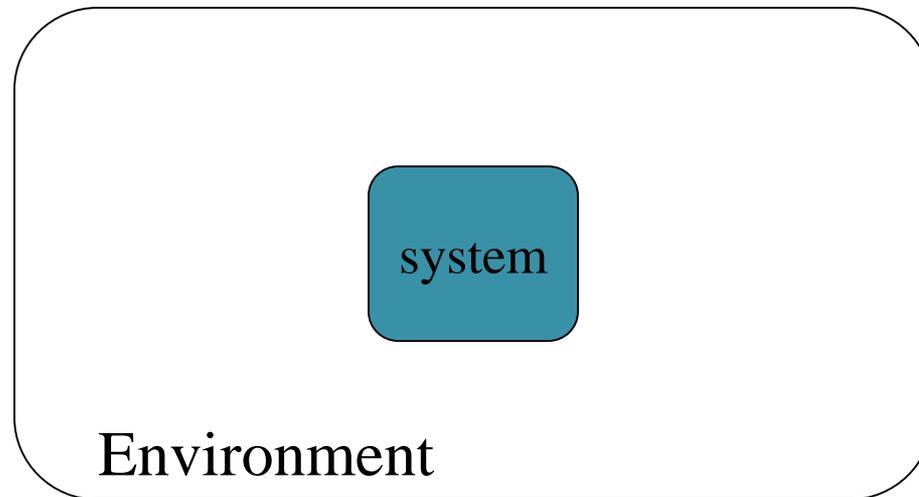
- essential properties arise from the relationships between its parts
- understanding of a phenomenon within the context of a larger whole

Web of life consists of networks within networks
To understand life will be to understand networks



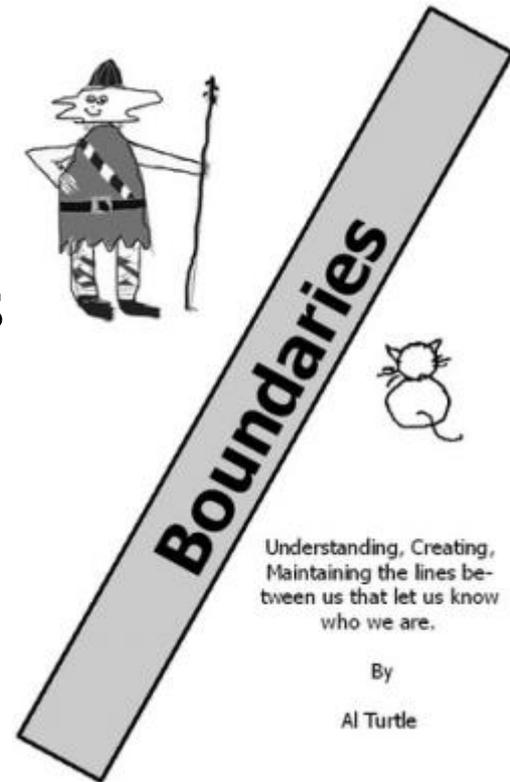
Systems Theory

- “...is, strictly speaking, not a theory of systems, but of system-environment distinctions.” *on Luhmann p. 40*



Boundaries and otherness

- “The prerogative of realization of internal system structure is that of environment.” *Patten 1978, p.211*
- “By constructing itself as a system, a system also constructs its understanding of the environment.” *Moeller 2006, p. 16*



Environment

System

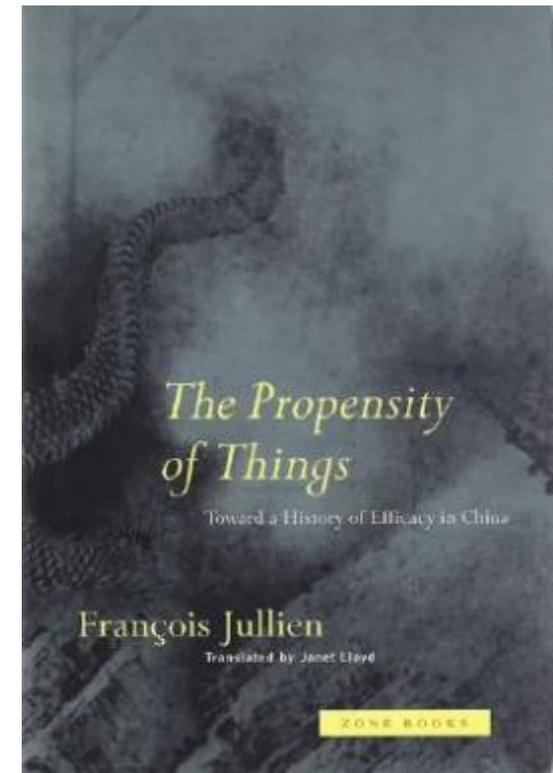


Every object defines two environments

Boundary separates the definable “environ” from the unknowable environment: A system is embedded in and open to its environment

History in East and West

- In the West, history is explained on the basis of causality
- Chinese tradition, in contrast, gives priority to relations



Knowing in East and West

- Why was Greek thought so concerned with extricating “being” from becoming, whereas in China the only reality is change itself?
- The essential difference is that Greek thought introduced order into becoming from the outside (on the basis of numbers, ideas, forms), whereas in Chinese thought, order is conceived as lying within becoming; it is what makes becoming a process.

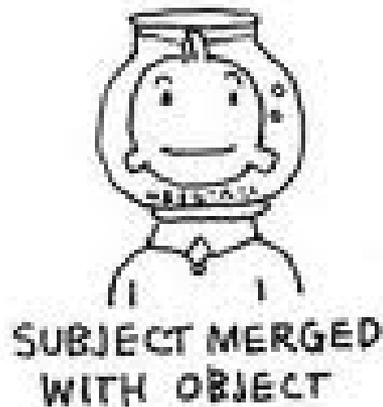


object-subject duality

- Aristotle declared, the two contrary principles “cannot act upon each other,” “do not change into each other”, and “are mutually destructive.”
 - In logical terms, they are mutually exclusive.

object-subject integration

SUBJECT OBJECT DILEMMA

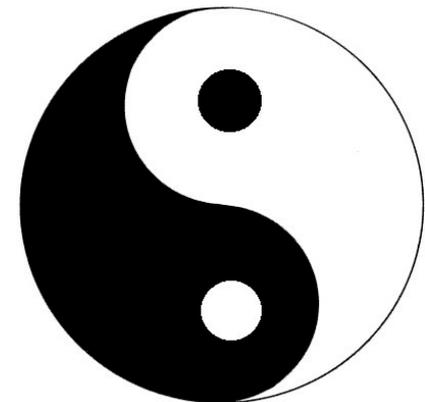


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The tradition insists that they oppose each other and “contain each other”:

Yang, as within yang there is yin; it softens the density of the yin, the yin softens the personification of the yang.

They proceed from the same primordial source and mutually give rise to each other's



Bifurcation between Greek and Chinese thought

- Aristotle's statement could be literally reversed: there certainly *is* a “natural disposition” through which contraries interact, and that interaction is both spontaneous and continuous (continuous, in fact, because it is spontaneous).



materialization without matter

- There is no need to posit a “third term” to support their relation.
- The two contraries form on their own a self-sufficient configuration
- The propensity that stems on its own from their interdependence orients the process of reality
- there is constantly *materialization* but, strictly speaking, no matter. P 25 I

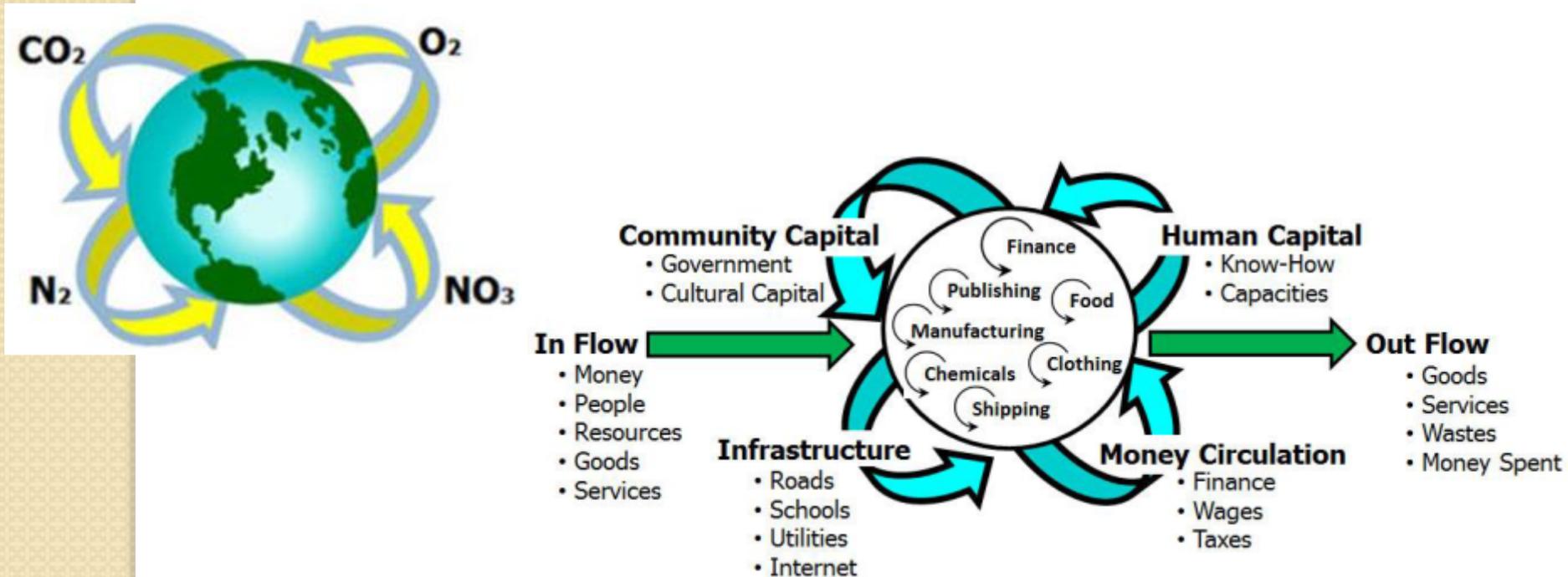
why networks are important

Conceptually: representing the systems as continuously connected

Practically: analyzing the system can help avoid unwanted or unexpected consequences

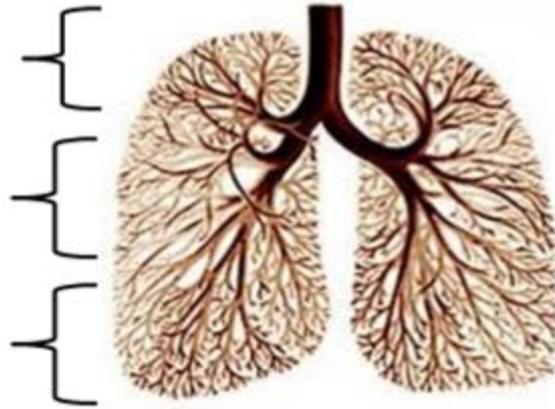
Energy Network Science

- Represent systems as interacting components
- Used to identify and quantify direct and indirect effects in the system
- Universal language



Energy, Matter, Information flow AND organization

The same power-law
ratio of small, medium
& large conduits holds
across scales
 N^x



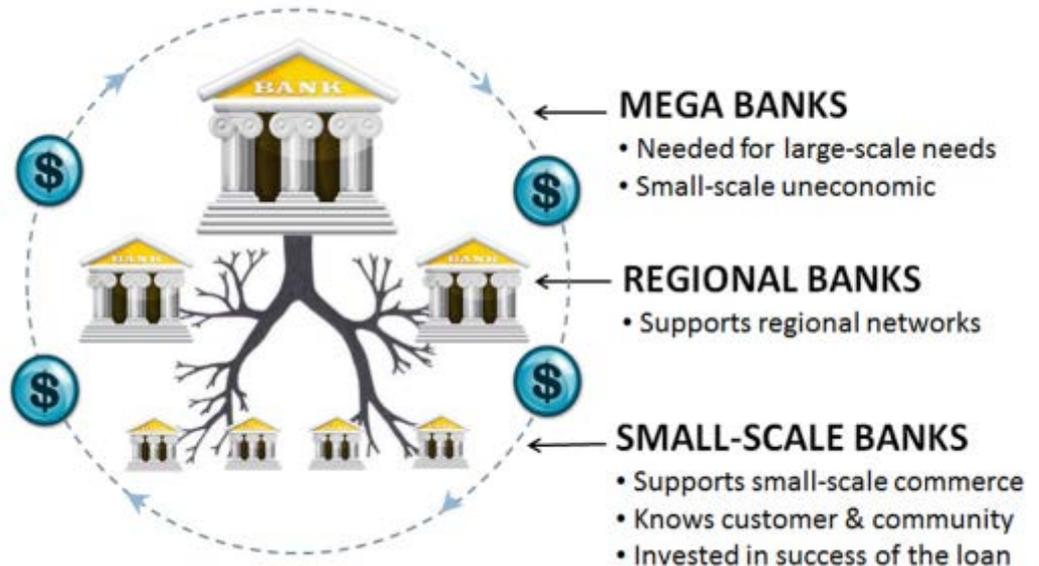
Lungs

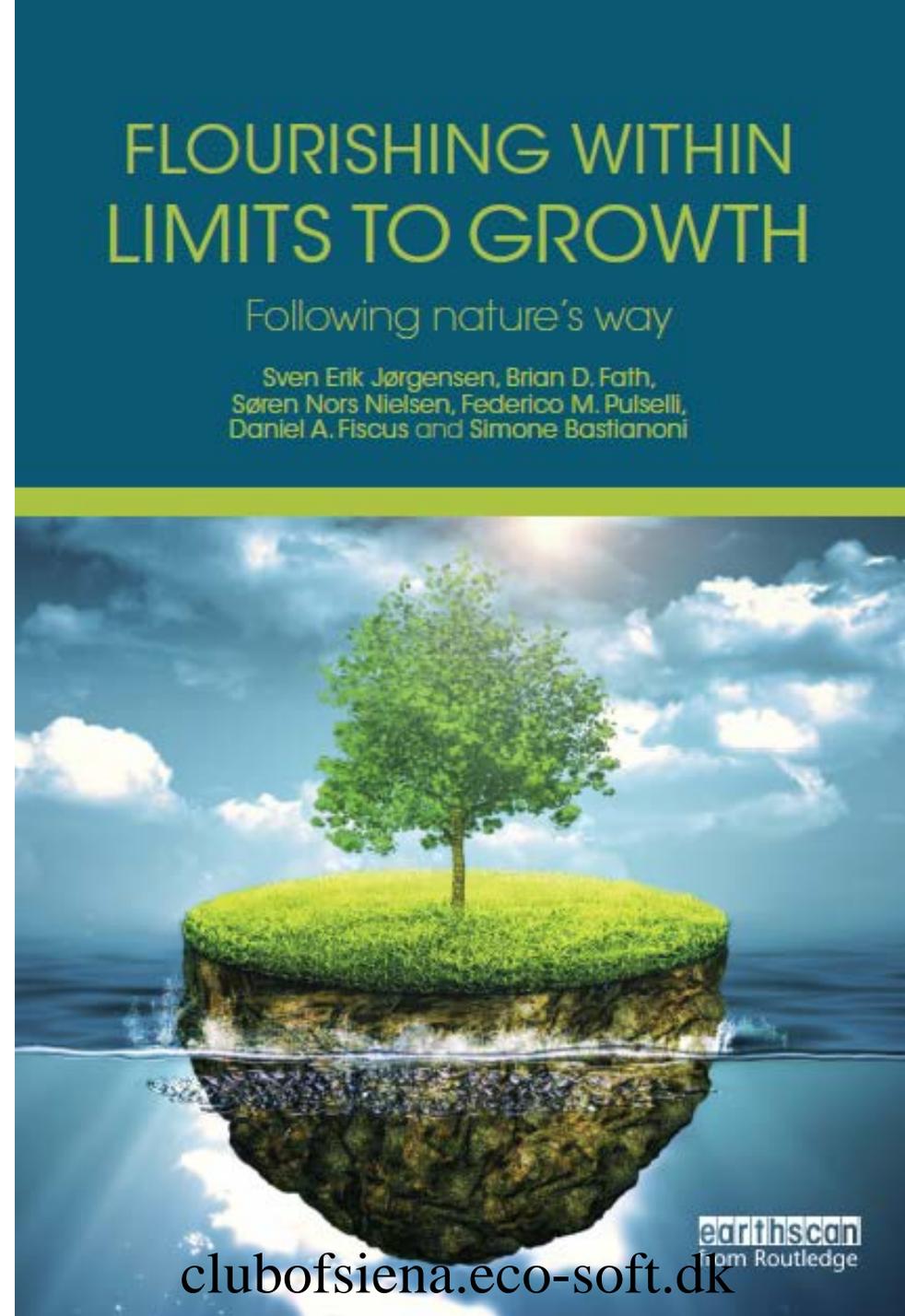
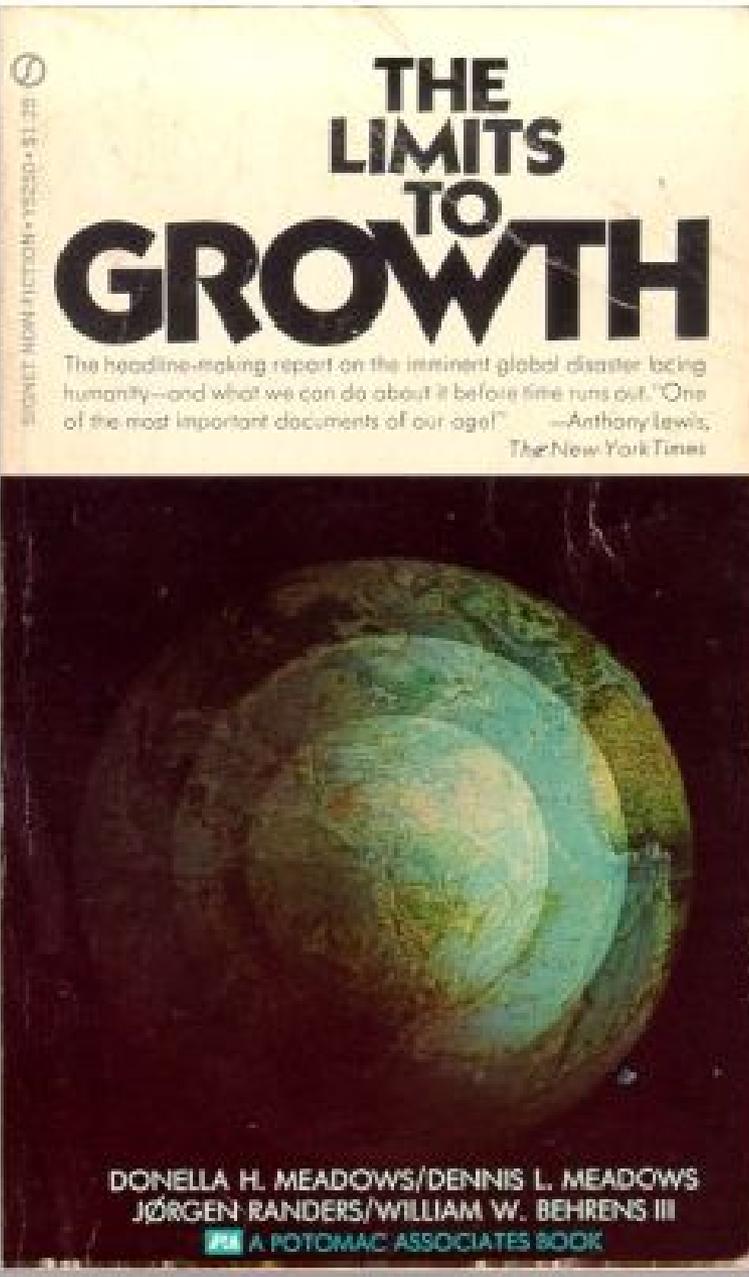


River Delta



Tree





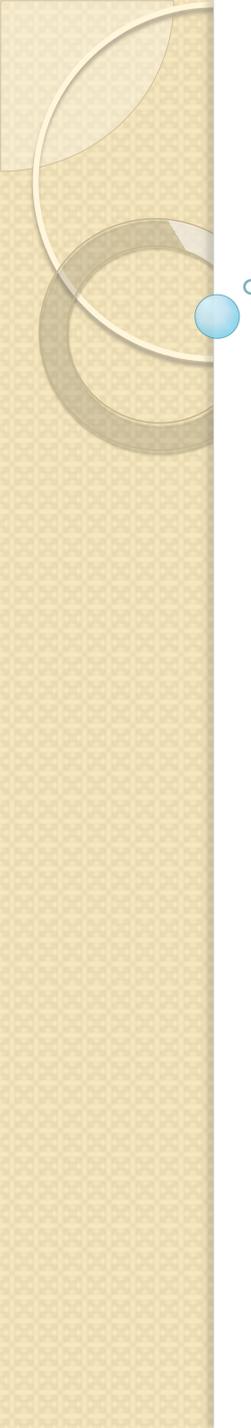
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14 properties of ecosystems

1. Ecosystems conserve matter and energy
2. There are no trashcans in Nature
3. All processes (in nature and society) are irreversible
4. All life uses largely the same biochemical processes
5. Ecosystems are open systems and require an input of work energy to maintain their function
6. An ecosystem uses surplus energy to move further away from thermodynamic equilibrium
7. Ecosystems use three growth and development forms: 1) biomass, 2) network, 3) information
8. Ecosystems select the pathways that move it most away from thermodynamic equilibrium
9. Ecosystems are organized hierarchically
10. Ecosystems have a high diversity in all levels of the hierarchy
11. Ecosystems resist (destructive) changes
12. Ecosystems work together in networks that improve the resource flow utilization
13. Ecosystems contain an enormous amount of information
14. Ecosystems have emergent system properties

What is sustainability?





**system sustainability:
becoming not being**

**Sustainability is a property of how things are
arranged: organization, configuration,
disposition, ...**

Closure

- “Operational closure: The results of systemic operations are at once more systemic operations.” *On Luhmann p. 14*
- “Function systems are operationally closed and function autopoietically.” *On Luhmann p. 101*



Structural Coupling

“...is a state in which two systems shape the environment of the other in such a way that both depend on the other for continuing their autopoiesis and increasing their structural complexity.” *On Luhmann p. 19*

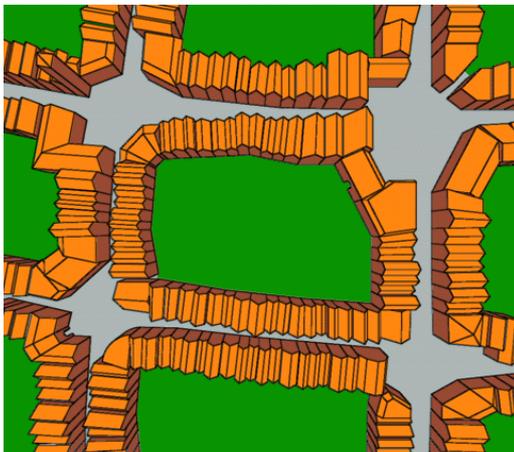


Continuation of this **IS**
SUSTAINABILITY

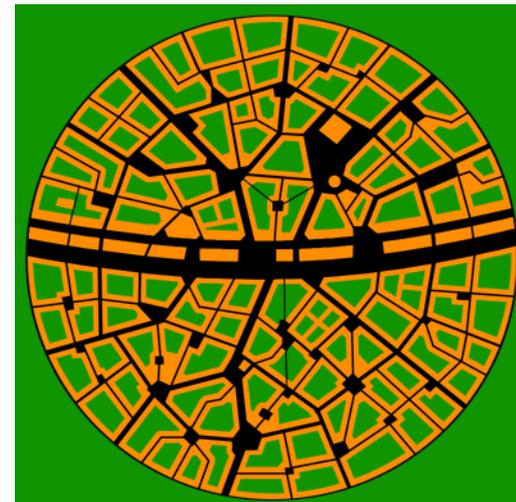
Centers

- “Centers are the fundamental primary entities. A center is any zone of coherence that occurs in space... may arise, initially as a minor non-homogeneity in space, through differentiation. **Each center is (recursively) dependent on other coherent centers for its own coherence.**”

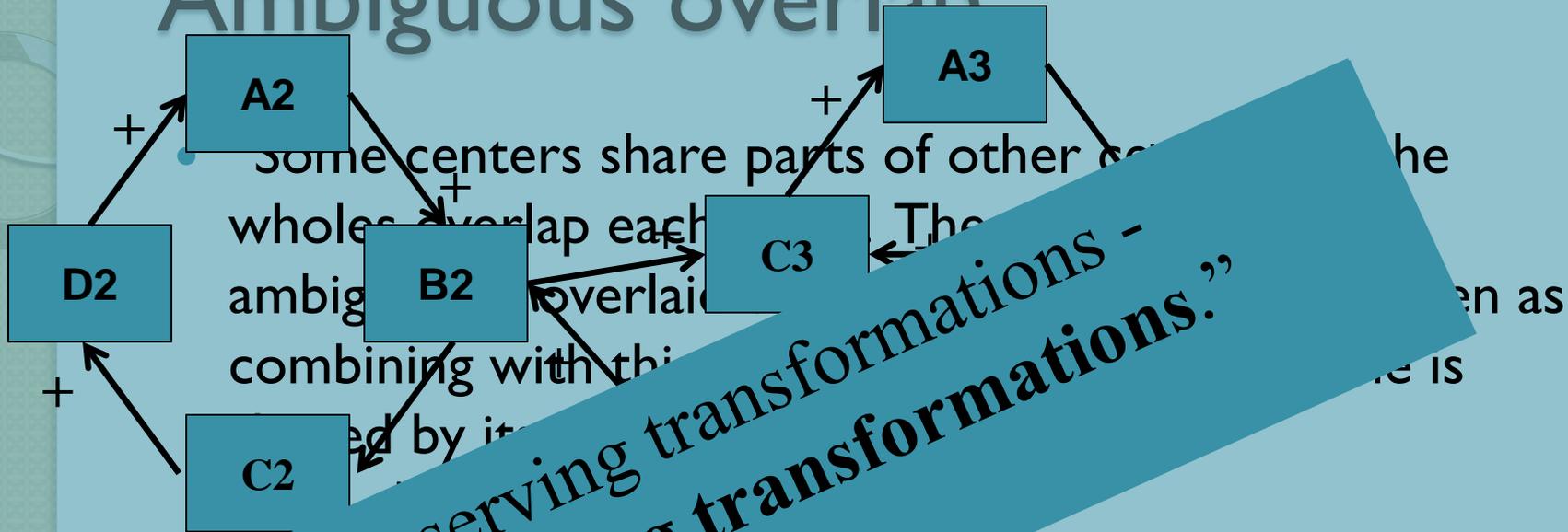
Alexander, p. 428



10 0 10 20 30 40 50 60 70 80 90 100 m

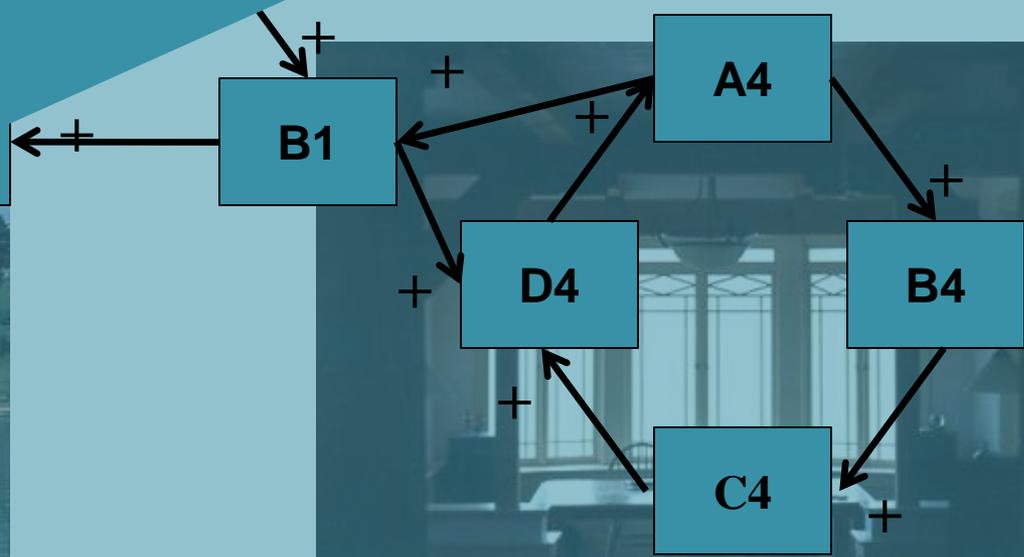


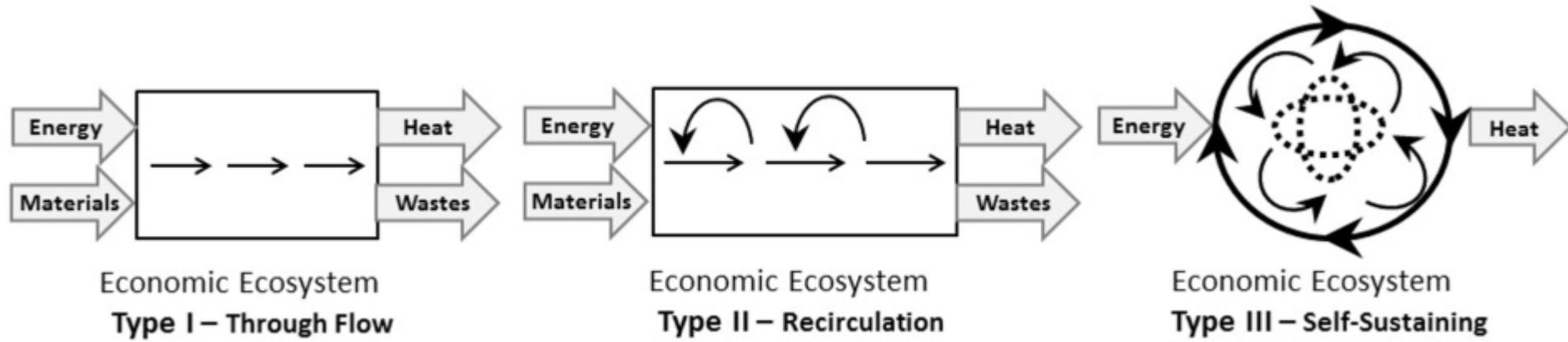
Ambiguous overlap



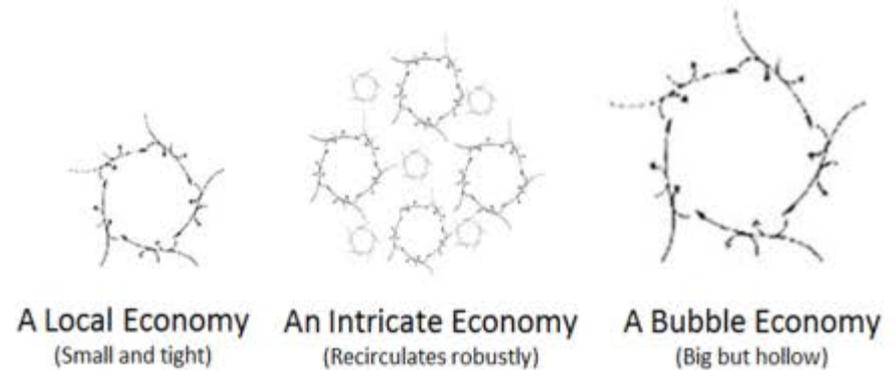
some centers share parts of other centers. The whole overlaps each other. The ambiguous overlap is overlaid. Combining with this is combined by it.

“Structure-preserving transformations - wholeness-extending transformations.”
Alexander, p. 428.



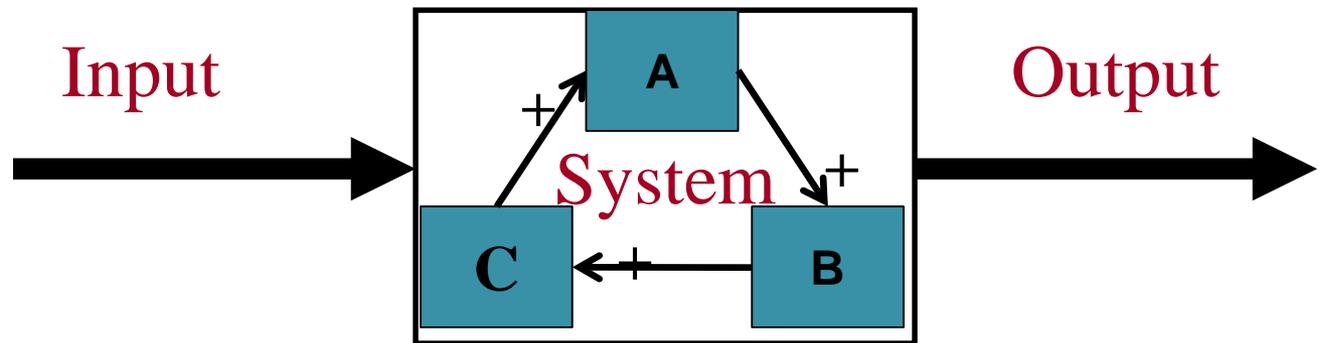


Key feature is forming and maintaining self-sustaining cycles



Conclusions: Sustainability is a property of interaction networks

- Linking together of processes that are positively reinforcing: autocatalysis
- Closure leads to niche extension and creation: Emergence of diversity and complexity
- Nature provides templates for design of sustainable systems



Take Home

- “It may be that **all self-sustaining systems are reciprocating.**” p. 126.

Jane Jacobs. 1969. *The Economy of Cities*



THANK YOU FOR YOUR ATTENTION



Systems thinking and systems analysis are necessary to understand sustainability