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Extending the 'Life' Concept to Complex Systems (CS)

exploring the proposal as a heuristic to better depict CS

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Outline of the presentation

1. Context: the question of defining CS
2. Proposal
3. Exploring the proposal (re-positioning concepts within the proposal + examples)
4. Summary
5. Potential use and example application

Context : no consensus/definite definition of CS

- **Dense and diverse body of knowledge** on CS with advances in a wide range of features:
  - Characteristics and properties (*e.g.*, interaction, emergence)
  - Structures and organisation (*e.g.*, networks, hierarchies)
  - Processes and function (*e.g.*, self-organisation, irreversible evolution, power law)
  - Behaviours and dynamics (*e.g.*, phase transition, self-organized criticality)
- Many avenues have been explored, but there is still **no consensus definition of complex systems** (instead, various set of properties // various fields of CS research).

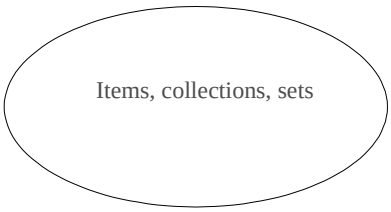
Context : finding common terms for CS

- Even **very diverse complex systems** (*e.g.*, climate, organism, society, language) can be seen to **have CS features in common**

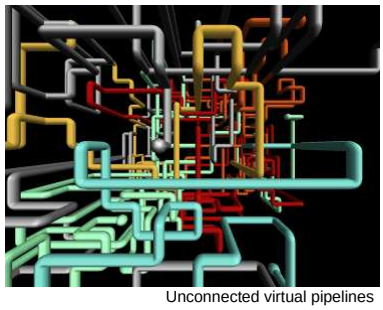
Proposal : explore the possibility of **using life-like properties to progress towards a common definition of CS**

Exposition based on a **classification of composite systems**

1st step of composite systems: sets of items with no interaction

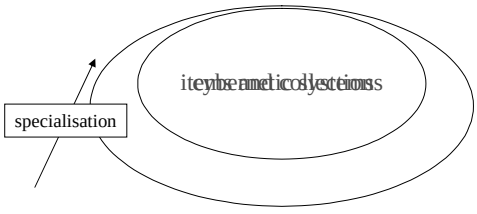


USUAL CLASSIFICATION OF COMPOSITE SYSTEMS



Unconnected virtual pipelines

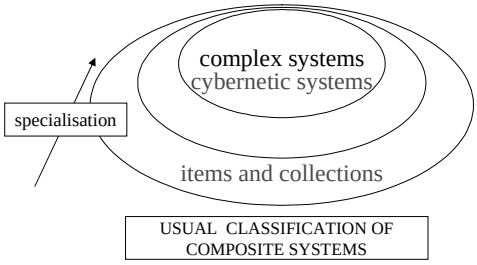
Connected systems with known and controled input, output and feedbacks

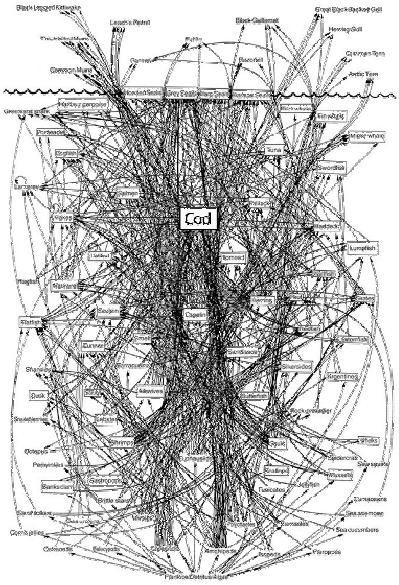


USUAL CLASSIFICATION OF COMPOSITE SYSTEMS

Piping system on a chemical tanker

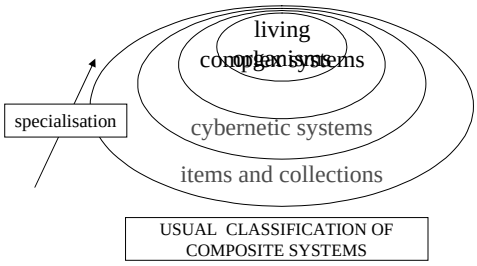
Diversified types of connection between items

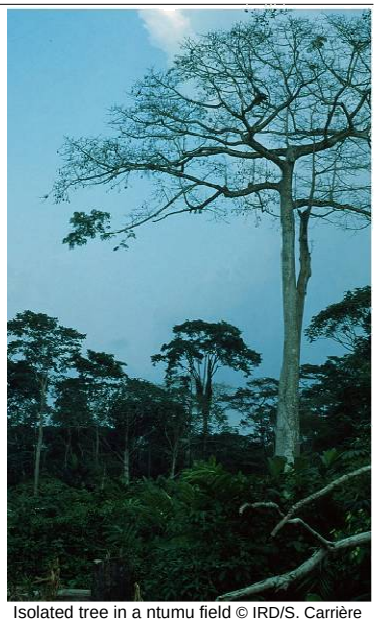




Northwest Atlantic cod food web

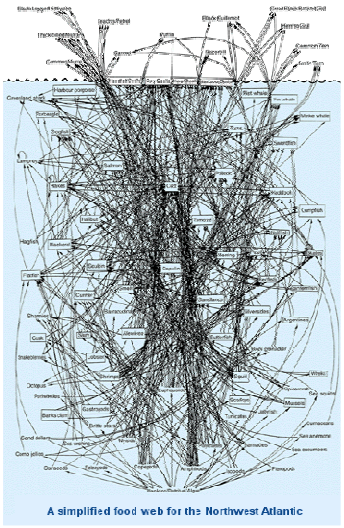
Life properties (reproduction, closure, self-,…)



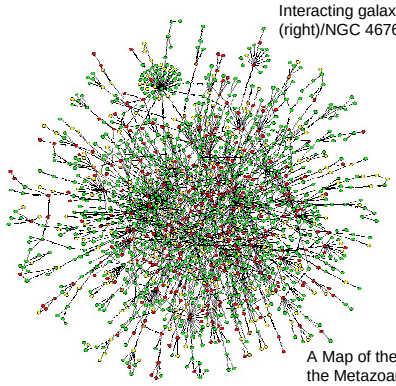


Isolated tree in a ntumu field © IRD/S. Carrière

Q: To what extent CS could be considered as ‘living things’ ?



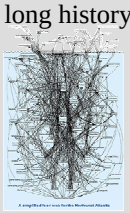
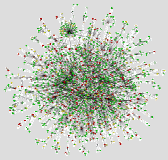
Interacting galaxies (NGC 4676A (right)/NGC 4676B (left)



A Map of the Interactome Network of the Metazoan C. elegans (Li et al., 2004)

Q: To what extent CS could be considered as ‘living things’ ?

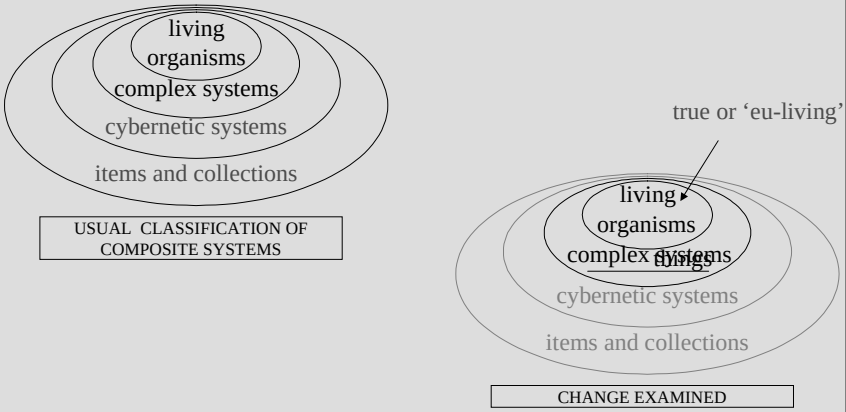
- Few attempts to qualify complex non-living systems as living or life-like entities (rivers, social or cultural structures).
- However in such situations, the authors generally refer to complex adaptive systems, which are particular, sophisticated, systems (great diversity, organisation, long history).


Proposal: explore the possibility of **considering any CS within a general category, ‘living things’.**

(‘any’ is the compulsory condition for a general definition)

Proposal



Reminder: approach interesting in terms of its heuristic value (generating questions, refutations, corroboration, refining the definition domain)

Re-positioning CS and life concepts within the classification proposed

Example as a reference for living/complex systems: a vertebrate

- metabolism
- reproduction
- organs, functional subparts
- functional organization
- ontogenesis, evolution, growth
- dispersal, motion
- death
- **lifespan**
- **adaptation**
- autopoiesis
- homeostasis
- **birth**

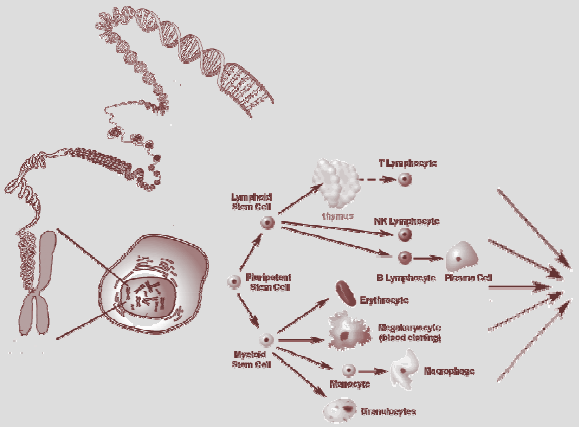
Properties to examine (nb: scrambled order)

Positioning Concepts Within the Classification Proposed

1. Birth ⇔ **emergence** (unprecedented, something (a monad) arising from other things) bringing a 'living thing' into **recognizable existence**

   – **Acquiring an identity** by means of emergence becomes one of the cornerstones of the equivalence between complex systems and living things.

It would follow that the whole hierarchy of Nature would be unified as a complete hierarchy consisting of 'living things' coming into existence



cosmos

Stellar systems, clusters, galactic filament, ...

planet (biosphere, weather)

populations (biocenoses, societies)

organisms

organs, physiological systems,...

cells (vegetal, animal)

DNA, proteines, nucleotides, ...

molecules (CGTUA, AA)

atoms (C,H,O,N)

quarks (/ superstrings

: continuum of *(i)* functional, *(ii)* Spatial and *(iii)* time scales

Positioning Concepts Within the Classification Proposed

2. Lifespan ⇔ **irreversible stepwise evolution** of the system over a given time period

   – The system emerges **into a changing environment**, with which it establishes relationships with irreversible effects.
   – The **complex interplay between the CS and its environment** leads to a 'story' of the CS – a 'life time'.

Lifespan as the irreversible evolution of CS after emergence

- Two levels for lifespan

1. Evolution in which successive **changes are not stored**: river water irreversibly becomes lake water, waterfall water, etc.,
2. Construction with memory in which **changes leave an imprint** on the living system, affecting its future behaviour and fate (a community becomes a society, a culture, etc.)

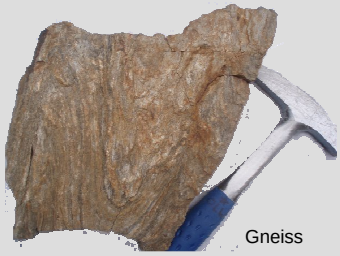
Test case at the edge of the proposal: a breaking wave

- Distinctive feature : short life time
- Pros: Complex behaviour (emergent, dispersal, motion, death, lifespan, irreversible dynamics, history, transformation, tipping, adaptation, homeostasis, openness, birth, identity, unity, wholeness, emergence, …)
- Do not hold: reproduction, metabolism, organs

→ 'living thing'

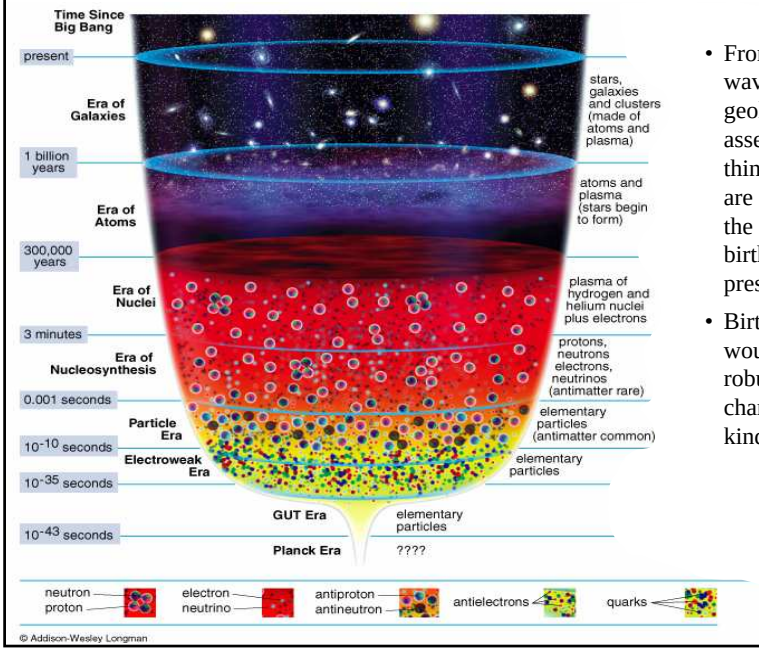
Example of questionable status: a stone

- Pros: emergent-birth, irreversible lifespan
- Cons: ~ closed system
- Distinctive feature :
  - **transformation** at geological time scale (*e.g.*, metamorphism)
  - Stay for long periods in metastable states
  - long lifespan


Gneiss


Gneiss

Consequence: life span range of 'living things'

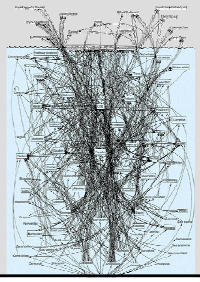
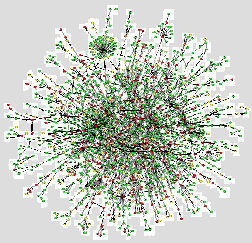


- From a breaking wave to a geological assemblage, 'living things' **lifespans** are spread all over the spectrum from birth of matter to present.
- Birth and lifespan would be two robust concepts to characterize any kind of CS

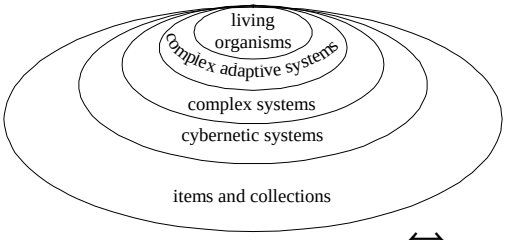
Positioning Concepts Within the Classification Proposed

3. Adaptation and self-:

- extends well beyond the subset of biological organisms, and includes non-living (in the strict classical meaning) items, such as markets, fisheries, language, or the Internet.
- Do not characterise all CS (*viz.* 'living things') but rather introduces the particular 'complex adaptive systems' category between the 'living things' and the 'living organisms' category.

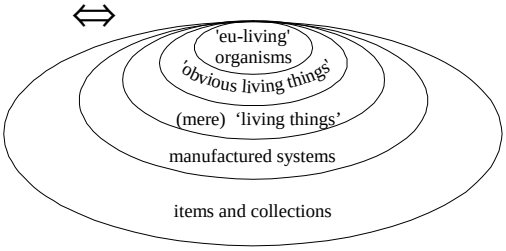




Possible classification including CAS



USUAL SENSE

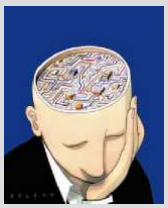
⇔



APPROACH EXAMINED

Example in the immaterial world (1/2): an idea
or a meme (Dawkins, 1976)

- Pros: almost all the properties of the reference case (reproduction, component parts, …)
- Cons: death ?
- Distinctive feature : immaterial



Example in the immaterial world (2/2): a fire

- Pros: almost all the properties of the reference case (metabolism, component parts, …)
- Cons: ethereal ?
- Distinctive feature: immaterial

⟶ ‘living things’

Other concepts discussed within the paper

- Birth / emergence
- Lifespan / Ontogeny, morphogenesis, maturation, learning, history, growth and evolution
- Adaptation and self-
- Death
- Reproduction
- Diversity or ‘polymorphism’
- Homeostasis, autopoiesis
- Input

Summary

- Within the astounding variety of CS, each specific case demonstrates or lacks one or the other life property (-> not 'harmless')
- Birth (emergence) and irreversible lifespan (interplay with the environment) are the two major concepts descending from life features; they are proposed as threshold criteria for defining CS.
- They both ($t_0, \Delta t$) can be expressed as quantified variables in universal units (date, time) within the CS sphere
  - and thus could **allow intercomparison within the wide diversity of CS**

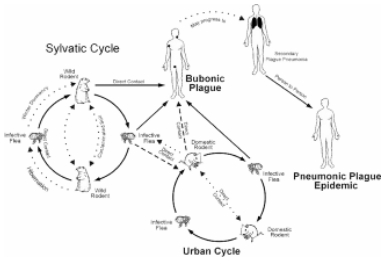
Potential use

1. Using life properties to characterize and identify CS

2. Assigning life properties to CS as a mean to encompass the whole variety of complex systems with transversal concepts

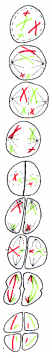
   - Example application: multidisciplinary modelling of rodents dynamics (project in progress)

Rodent hosts – parasites dynamics: example set of research scales

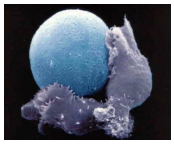


Epidemic diffusion organisms

Co-evolution communities

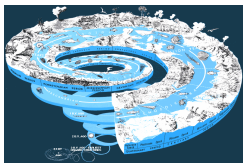


Genetic adaptation
chromosomes
/genes



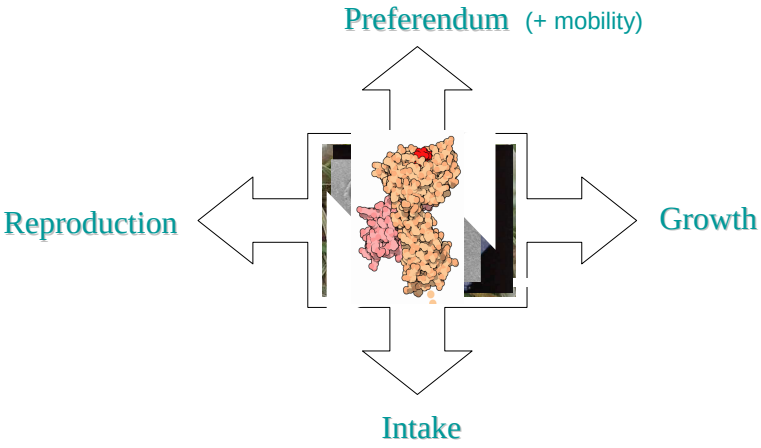
Immune reaction
cells, proteins

Evolution
clades, species



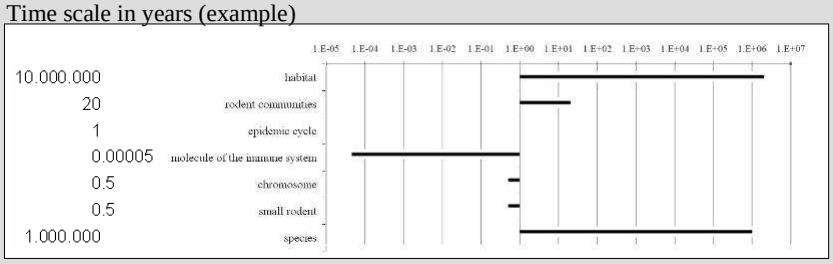
All scales are legitimate for a given question
→ Integration modeling scheme => search for common primitives

Search for common primitives inspired from life science: species survival example

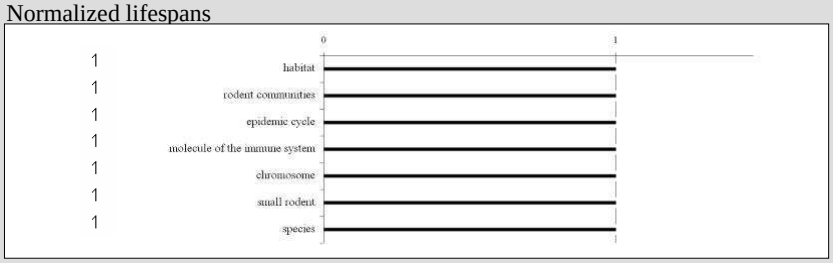


Using lifespan to normalize co-occuring CS (work in progress)

Time scale in years (example)



Normalized lifespans



All 'living things' **participate equally to the dynamics** (-> common time unit: computer simulation step + events).

Images sources:
- bordalierinstitute.com
- en.wiklpedia.org
- futura-sciences.com
- IMMA
- Nature
- webshots.com
- …

Eagle nebula (detail)

Glacier - Alaska

Thank you for your attention

(examples of CS/'living things')

Lenticular cloud