Requirements for Open-Ended Evolution in Natural and Artificial Systems

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(Informal) working definitions

Open-ended evolution is:

“evolutionary dynamics in which new, surprising, and sometimes more complex organisms and interactions continue to appear”

even more informally:

“a system where the continued evolution of novel forms is so interesting that the researcher is unwilling to press the ‘off’ switch”

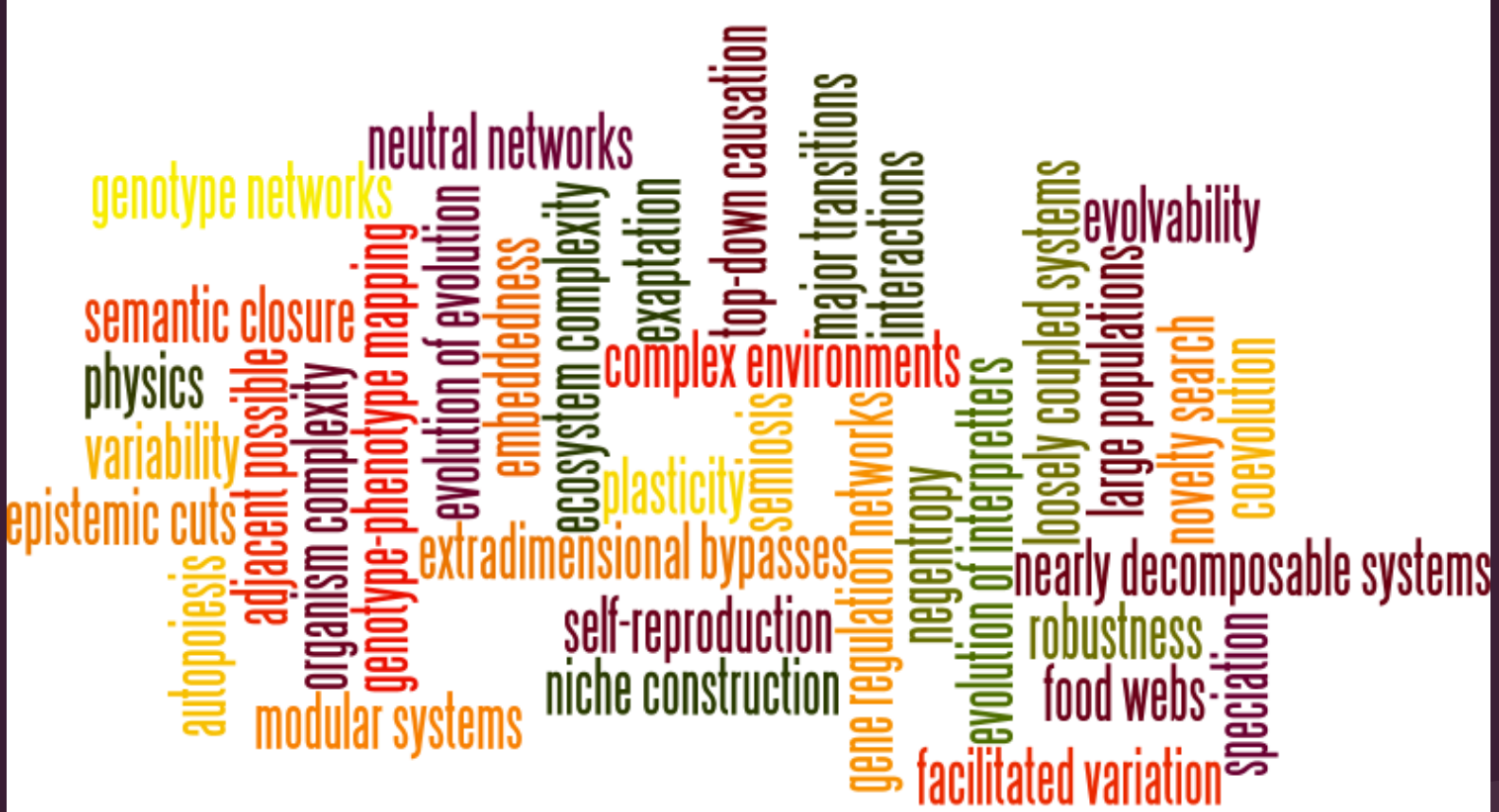
OEE vs Evolvability

Evolvability

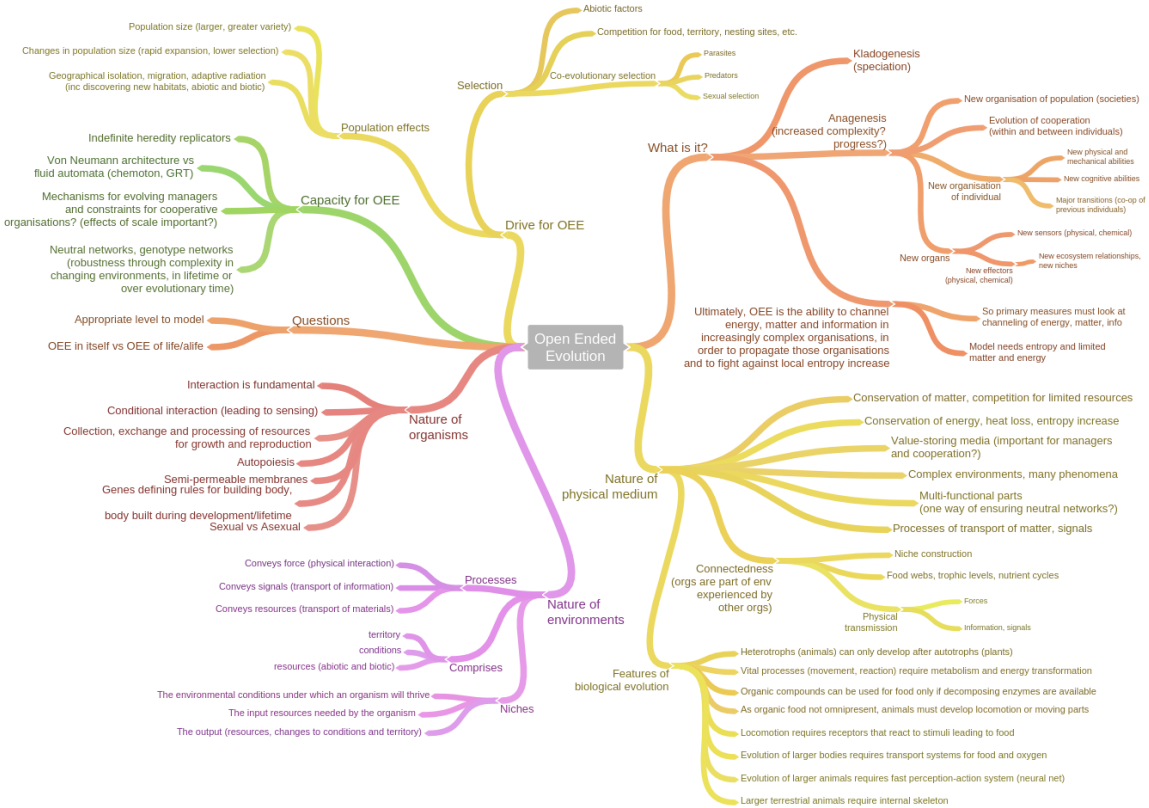
- the ability of a specific genotype-phenotype mapping to increase the proportion of favourable mutations

Open-Endedness

- drive for on-going evolution
  - co-evolution
  - niche construction
  - utilizing the complexity of the environment
  - new forms of organisation



Many concepts are relevant to OEE!



An initial attempt at organising concepts…

Five fundamental requirements

#1 Robustly reproductive individuals

- (*Here we are talking about robustness of ecological individuals, not populations*)
- Von Neumann's self-reproducing cellular automata are not robust
- Tierra and Avida hard-wire robustness into the system
  - this limits evolutionary potential
- What are the appropriate ways to achieve robustness in artificial life systems?

Five fundamental requirements

#2 Individuals capable of producing more complex offspring

- Could be achieved in (at least) two different ways:
  - A single individual is capable of producing offspring of greater complexity than itself
    - e.g. Von Neumann's solution (interpretted/uninterpretted structure)
    - Implemented in Tierra, but interpretor is hard-coded and not evolvable
    - Also wish to evolve other aspects (e.g. genetic transmission, organisation of genome, mutation rates, etc): "evolution of evolution"
  - Two or more individuals are jointly capable of producing offspring of greater complexity than any one of its parents
    - Horizontal gene transfer, symbiogenesis. Much less explored in ALife systems

Five fundamental requirements

#3 Mutational pathways to other viable individuals

- Rensch's (1947) "improvements allowing further improvements"
- Much relevant work in recent literature
  - Neutral networks, genotype networks
  - Evolvable G-P mappings, facilitated variation
  - Evolution of modular / loosely coupled / nearly decomposable systems
  - Extradimensional bypasses, exaptation, multimodal bridges

Five fundamental requirements

#4 A medium allowing the possible existence of a practically unlimited diversity of individuals and interactions

- Complex environments, “toy bricks”, “sorta” evolution
- What features of the environment are required for:
  - Not just evolving increased computational and information processing capabilities, but also:
  - Evolving new sensors and effectors (new inputs and outputs), an important part of biological OEE
  - And new organisations (major transitions)

Five fundamental requirements

#5 Drive for continued evolution

- (Natural) selection pressure from limited resources, competition, etc., creating an adaptive landscape
- Continued selection pressure through changing adaptive landscape
  - Individuals being part of environment experienced by others
    - leading to co-evolution, niche construction, ecosystem engineering, etc.
    - Connectedness: food webs, transmission of forces, signals: “just being there”
  - Also change through diffusion of species to new environments
    - (e.g. allopatric speciation)

Five fundamental requirements

1. Robustly reproductive individuals
2. Individuals capable of producing more complex offspring
3. Mutational pathways to other viable individuals
4. A medium allowing the possible existence of a practically unlimited diversity of individuals and interactions
5. Drive for continued evolution

Paper available at http://www.tim-taylor.com/

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