Requirements for Open-Ended Evolution in Natural and Artificial Systems

Tim Taylor
Department of Computer Science and York Centre for Complex Systems Analysis
University of York, UK


tim@tim-taylor.com

@timtaylorUK

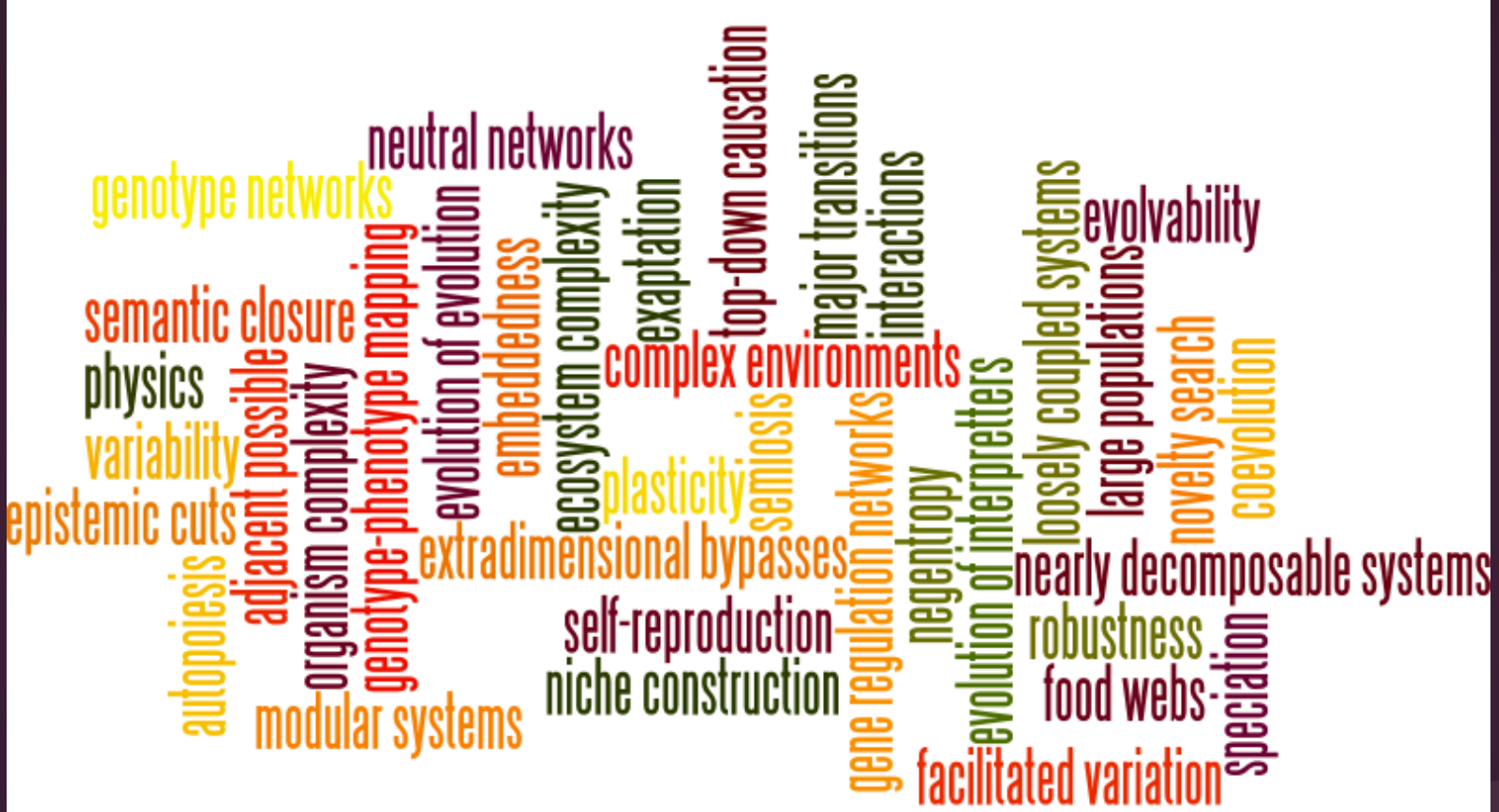
(Informal) working definitions

Open-ended evolution is:

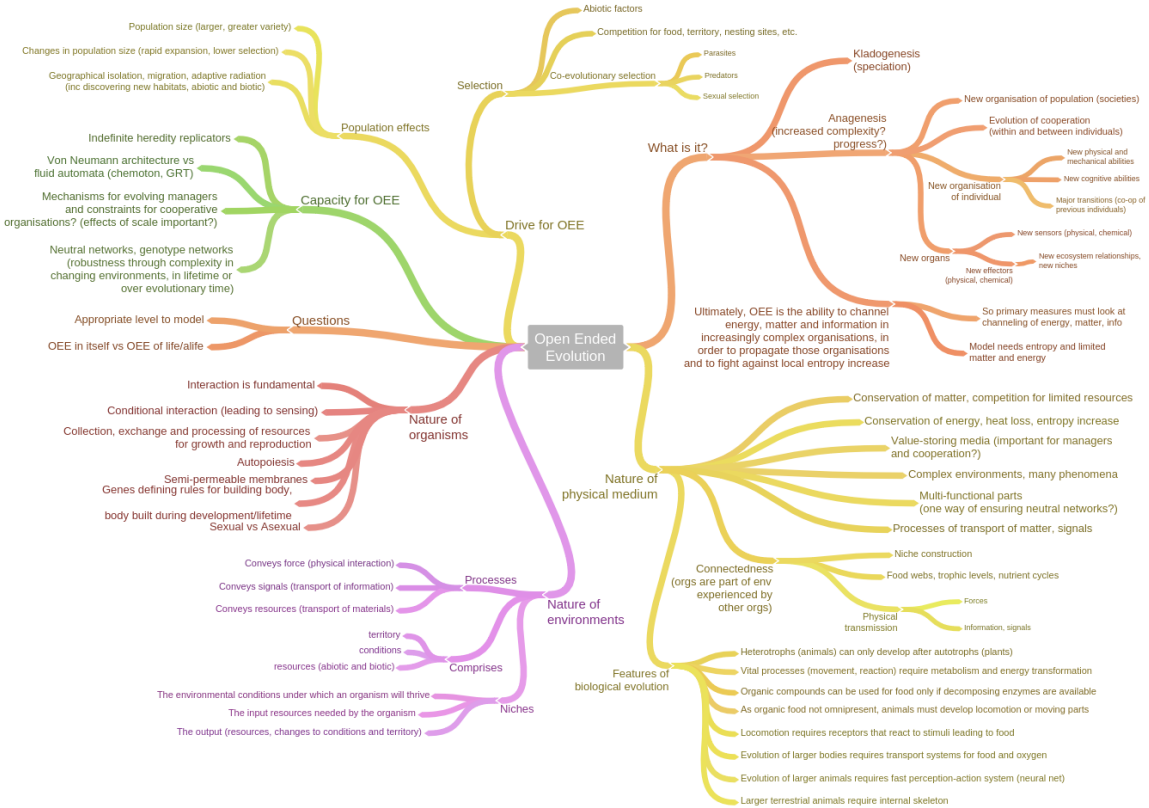
“evolutionary dynamics in which new, surprising, and sometimes more complex organisms and interactions continue to appear”

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”



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
    - 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

I'm also presenting these ideas at the EvoEvo Workshop on Friday, paper available at http://www.tim-taylor.com/

tim@tim-taylor.com @timtaylorUK