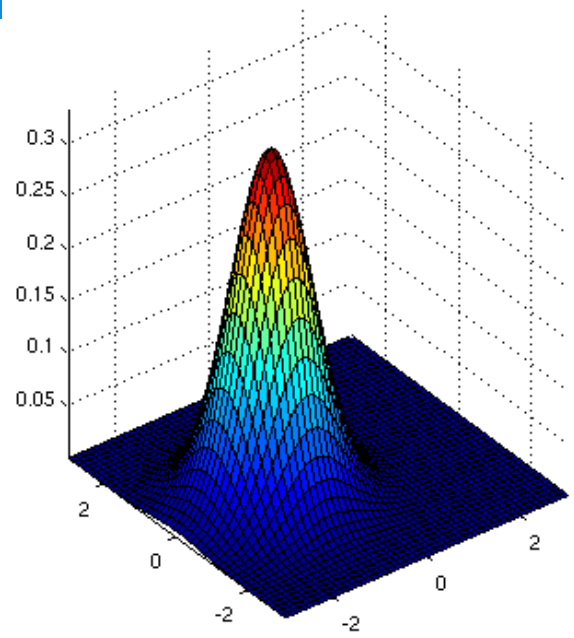
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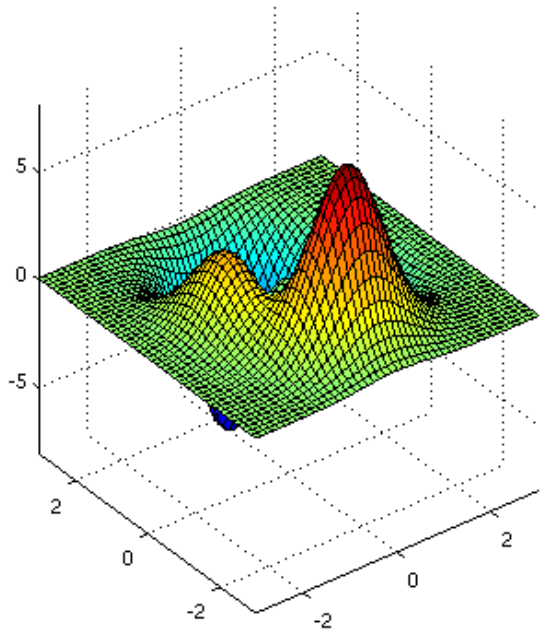
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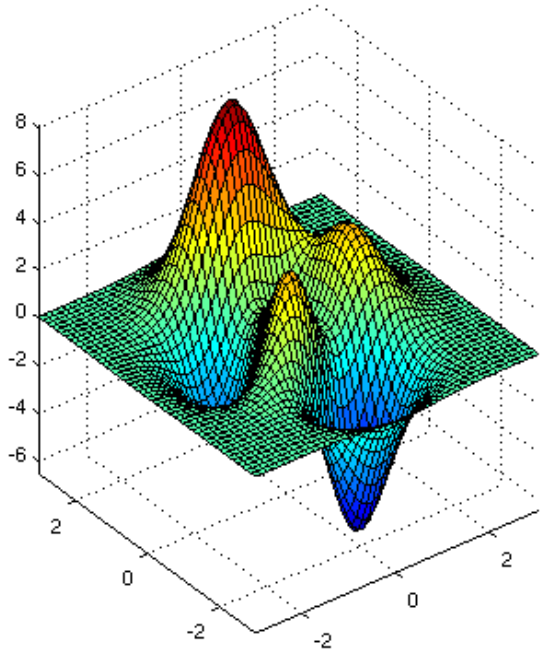
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Spm 9550: Evolution

Dr. ir. Igor Nikolic

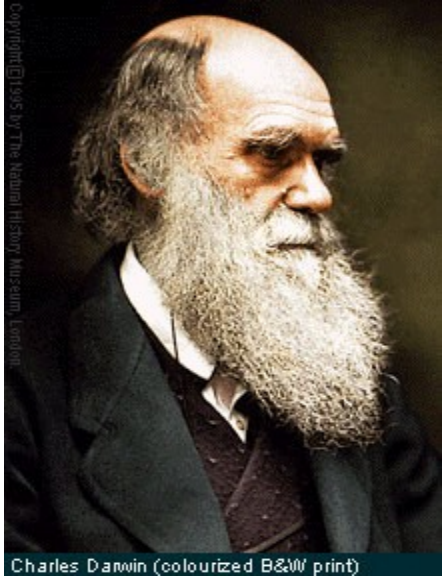
12-03-10

Lecture goals

- Understand the notions of
  - Evolution
  - Co-evolution
  - Coupled fitness landscapes
  - Intractability
- Understand the differences between biological and socio-technical evolution

Evolution

Evolution in nature



- Charles Darwin, 1859
  " The Origin of Species"
  - "Live, vary, multiply, let the strongest live and the weakest die"
- Evolution is an algorithmic process.
  - It is a answer to the how question
  - Not the why or where !

(Dennet, DC, Darwin's Dangerous Idea: Evolution and the Meanings of Life, Simon & Schuster; Reprint edition (June 12, 1996), ISBN: 068482471X)

Some properties

- Evolution is NOT teleological
  - no "*Grand Purpose*"
- Evolution is a local optimizer
  - survival of the most suited organism for the current situation
- Evolution is path dependent
  - more and more variations on less and less themes
- Evolution does not now know *sunk cost*
  - dinosaurs evolved over millions and gone in a few thousand years.

Co-evolution

Co-evolution

- At a general level, we conceive of co-evolution as dynamic interactions between two or more interdependent systems which account mutually for each other's development.

C. Rammel, S. Stagl, and H. Wilfing. Managing complex adaptive systems - A co-evolutionary perspective on natural resource management. Ecological Economics, 63(1):9–21, JUN 15 2007b. ISSN 0921-8009. doi {10.1016/j.ecolecon.2006.12.014}.

Co-evolution II

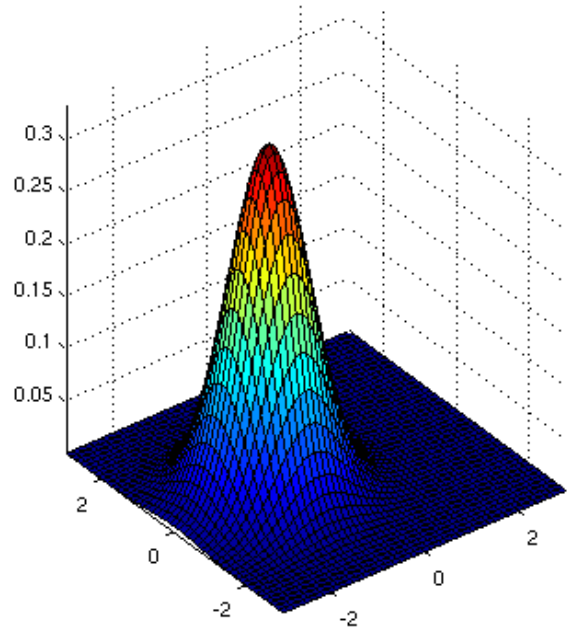
- co-evolution can be seen as the evolutionary process among two or more components/sub-systems/systems driven by reciprocal selective pressures and adaptations between these components/sub-systems/systems.
- Thus, a co-evolutionary system can be defined by the totality of all interacting components/subsystems.
- Moreover, co-evolutionary dynamics reflect different temporal, spatial and social scales, nested hierarchies, inevitable uncertainties, multidimensional interactions and contain emergent properties.

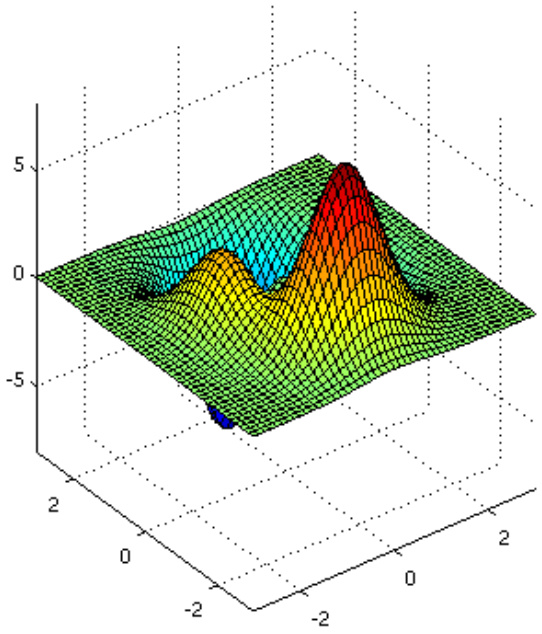
C. Rammel, S. Stagl, and H. Wilfing. Managing complex adaptive systems - A co-evolutionary perspective on natural resource management. Ecological Economics, 63(1):9–21, JUN 15 2007b. ISSN 0921-8009. doi {10.1016/j.ecolecon.2006.12.014}.

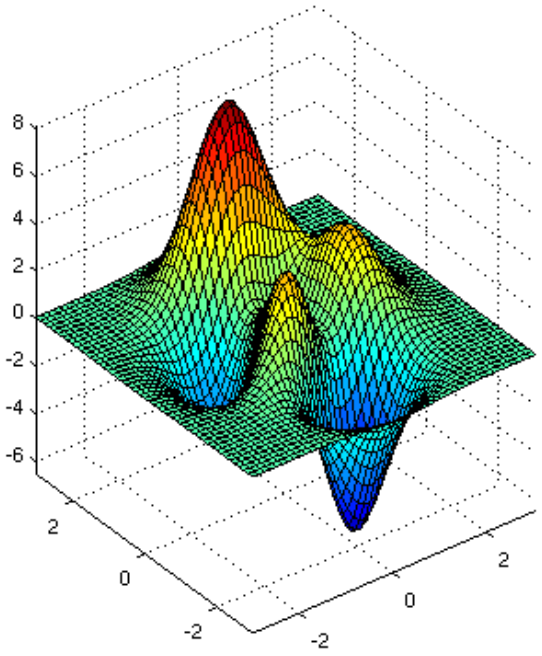
Coupled fitness landscapes

Coupled fitness landscapes

- the combined fitness landscape of the multiple species,
- as the species co-evolve, they attempt to find the peaks, where they are both at their maximum fitness.
- the evolution of one species changes the fitness landscape of the other, and vice-versa.



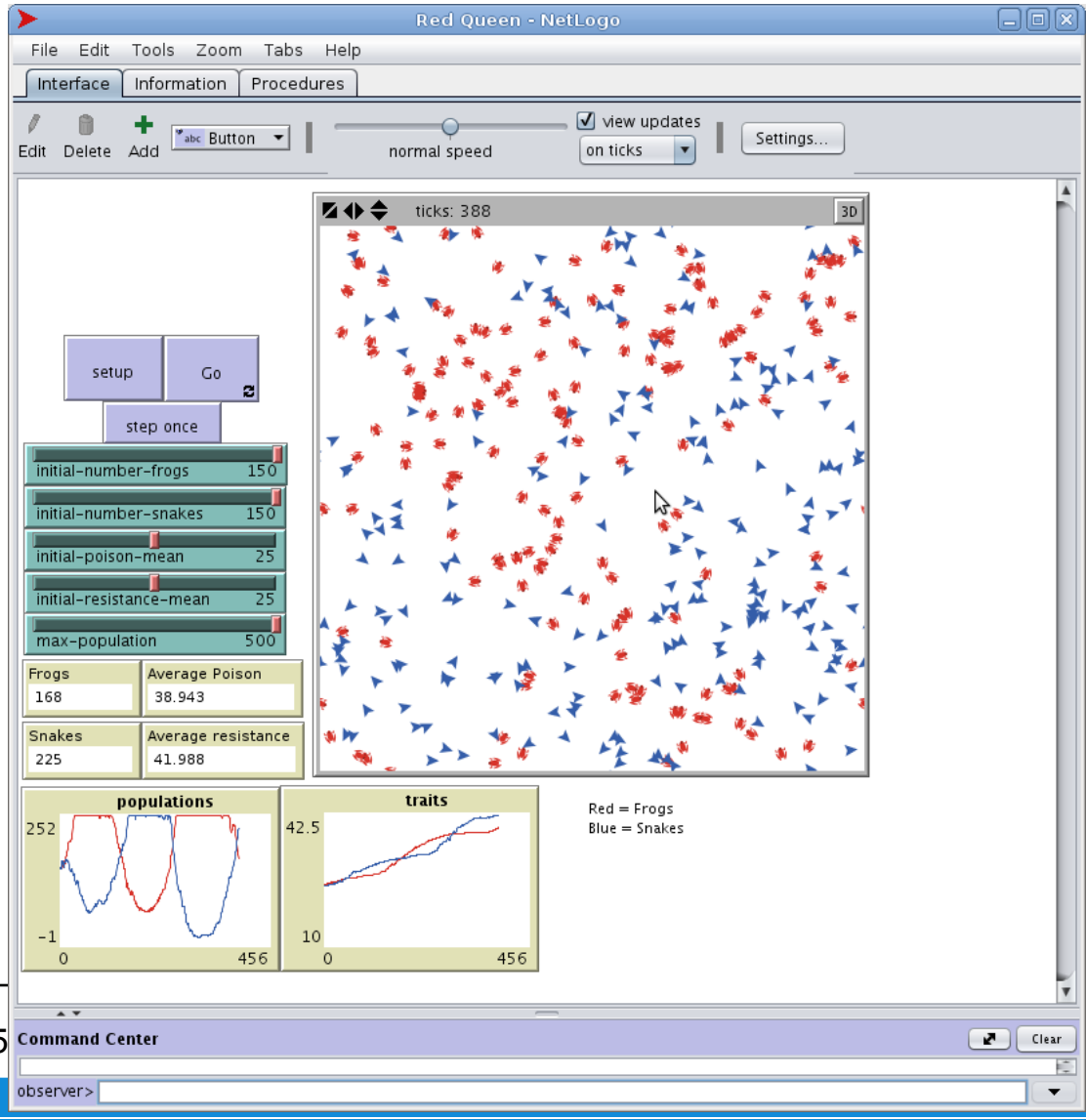




Red queen model

"It takes all the running you can do, to keep in the same place."

Lewis Carroll, "Through the Looking-Glass"



Intractability

Evolution is *intractable*

Problems that can be solved, but not fast enough for the solution to be usable
(Hopcroft, et al, Introduction to Automata Theory, Languages, and Computation 2007: 368)

- *That is, evolution is <u>not</u> NP complete...*
- *It exists in the EXPTIME/space*
- *Chess, Go, Checkers are examples of EXPTIME problems*

$$\mathrm{EXPTIME} = \bigcup_{k \in \mathbb{N}} \mathrm{DTIME}\left(2^{n^k}\right).$$

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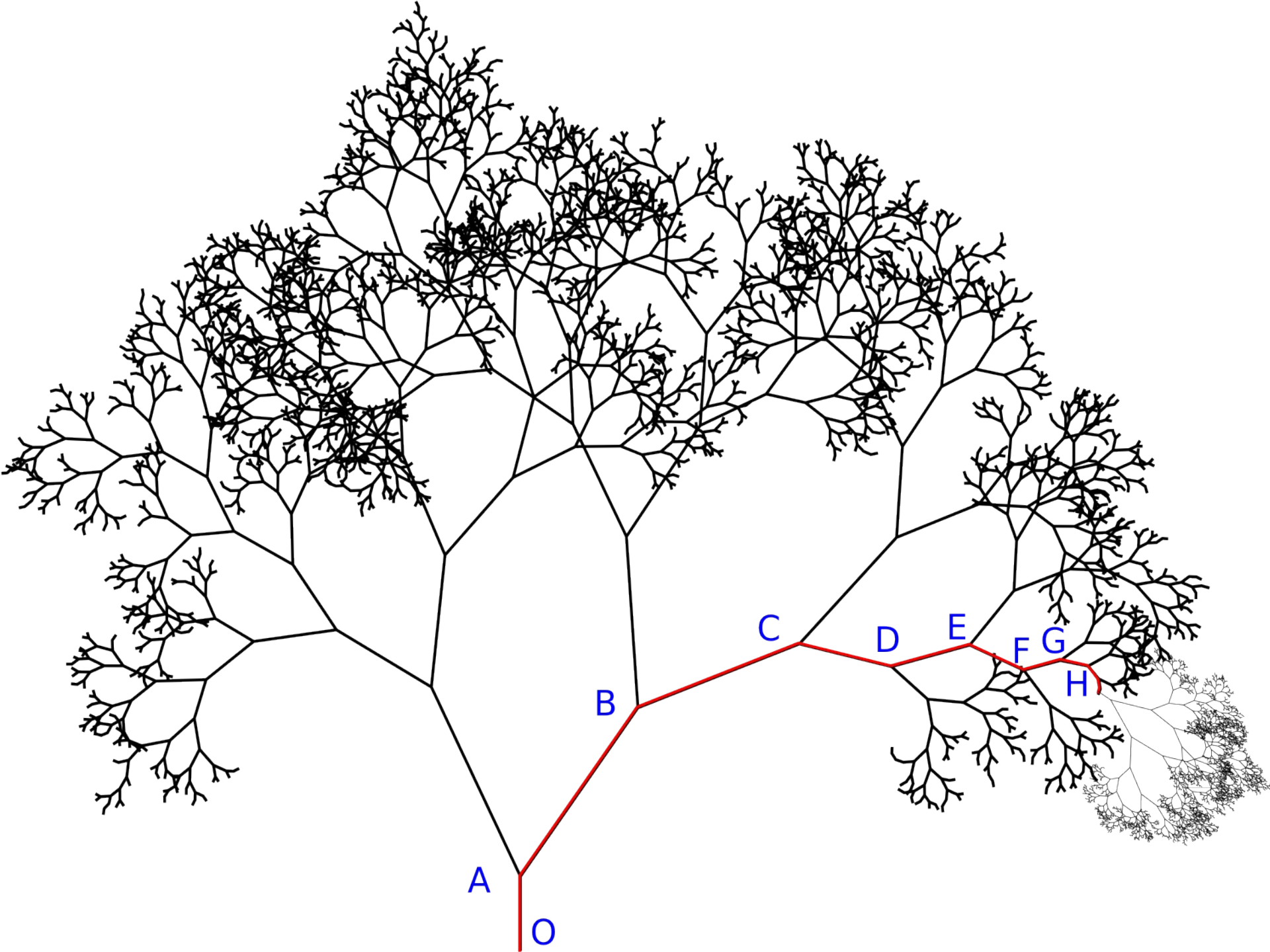
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Scale of intractability

- ***Übercomputer***
  - each electron in the universe (10^79)
  - has the computational power of today's fastest supercomputer (10^12 instructions per second)
  - each worked for the entire age of the universe (10^17 seconds)
  - would equal 10^108 computations
- evolutionary process with 100 variables, evaluated over 100 time steps.
- examine all possibilities, and thus be able to predict the outcome in advance = 2^(100^100), or 2^(10E199) calculations, or :
  2^100000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000
  00000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000
  http://www.cs.princeton.edu/introcs/77intractability/

No way to predict !

Human vs biological evolution

Evolution in biology

- Living organisms are both matter and information
  - "Boring stuff organized in interesting ways"
- Information is encoded in a chemical carrier, genes embedded in DNA
- Organisms
  - Live
  - Replicate,
  - Mutate in the process
  - and are selected out either by death or inability to replicate (e.g. Darwin Awards)
- In a physical environment that together with other organisms performs the selection

Evolution in social systems

- Information is encoded in our individual minds and collective culture
- "Memes" have been proposed as an equivalent to genes. What is the DNA ?
- What are the life, reproduction,mutation and selection of memes ?
- Many suggestions and ideas, no clear answers yet

Dawkins, Richard (1989). The Selfish Gene (2 ed.). Oxford University Press. p. 186. ISBN 0-19-286092-5.

Socio-technical co-evolution

- Co-evolution between social systems and the technology they create and use
- Society creates technology to use in a certain way
- Technology gets used in novel ways and shapes society.

- Examples are
  - Horses and European cities vs Cars/Trains and US cities
  - Energy production and power markets
  - Internet and copyright laws
  - Mobile phones and farmers in remote Indian villages
  - Vacuum tubes in radios, long before used in computers

Natural vs Social evolution process

- Seems to have a goal
  - Never stopping economic growth ?
- Seeks the optimum
  - But what is an optimum ?
- Is path dependant
  - Think fossil fuels
- Very sunk cost aware !

- Careful what to learn and what not to learn from nature, when thinking about society