

Emergence of emergence

Nicholas Guttenberg

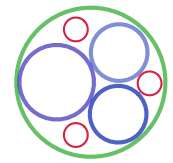
Earth Life Science Institute, Tokyo Institute of Technology, Japan

Norman Packard

Earth Life Science Institute, Tokyo Institute of Technology, Japan

European Center for Living Technology, Venice, Italy

ProtoLife Inc., San Francisco, CA

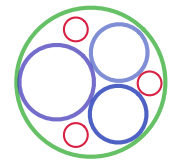


Emergence of evolution

The big question:

What dynamical processes lead generically to sequestration of information into units that

- have long-term stability
- control fast time scale dynamics
- can serve as evolvable elements



Previous work

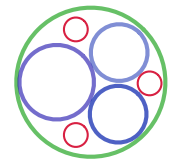
Previous work:

Evolutionary self-organization of cell-free genetic coding, Rudolf M. Fuchslin and John S. McCaskill, PNAS **98** no. 16 (2001)

On a kinetic origin of heredity: minority control in a replicating system with mutually catalytic molecules, K Kaneko, T Yomo - Journal of theoretical biology **214**, 563 (2002)

Current focus: understand dynamical mechanisms well enough to engineer systems that will naturally implement

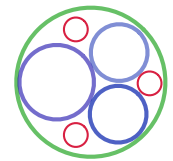
- information sequestration
- evolvability
- Robustification (error correction, etc)



Transition from

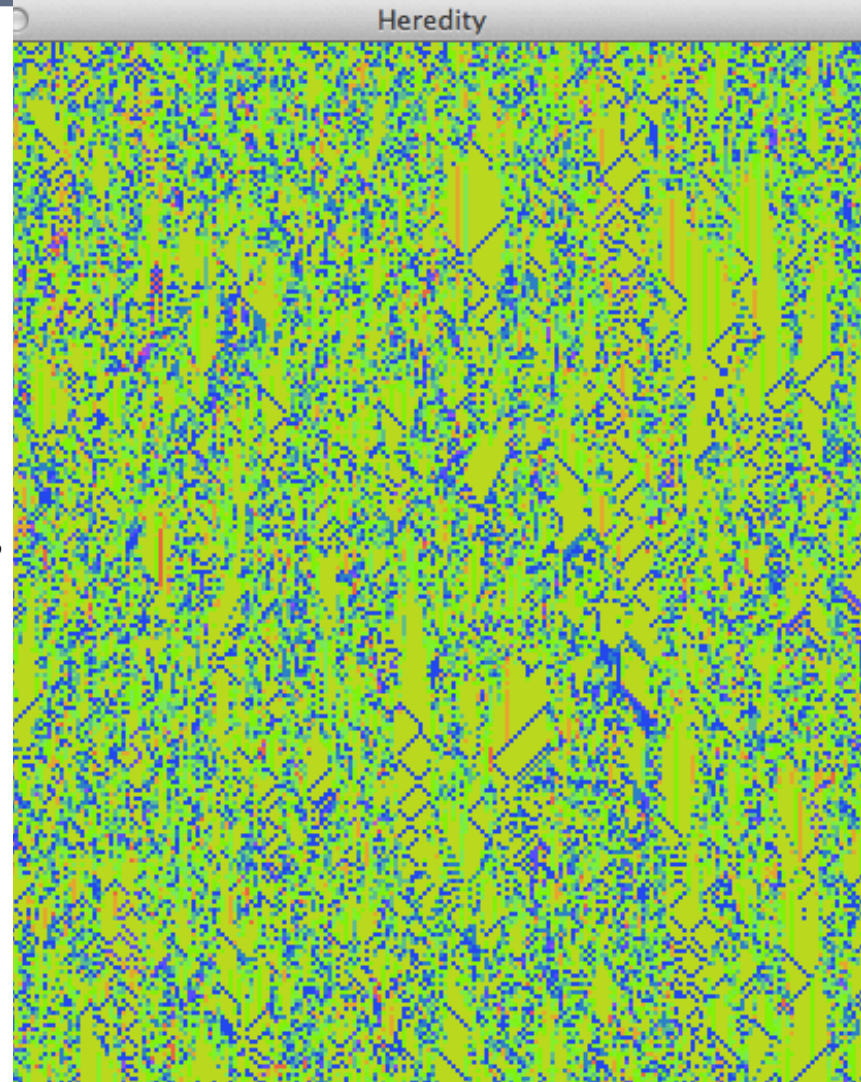
- ◆ 'kinetics': e.g. dynamical system governing concentration variations
 - Attractor dynamics
 - Stable long-term equilibrium statistics
- ◆ Evolutionary dynamics:
 - Formation of *dynamical canals*
 - Short term stability governed by informationally stable components
 - Long term instability, evolutionary innovation
- ◆ Dynamical mechanism:
 - Alternation between unstable (& neutrally stable) dynamics and contracting, fixed point dynamics
 - Tide pools, diurnal cycles, high-low temperature cycling...
 - Natural formation of information bottlenecks
 - Emergence of informationally stable components.

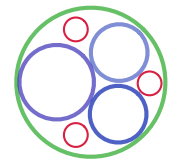
Abstract model example



- ◆ 1d spatial lattice (256 sites)
- ◆ Local variables: 100 coupled logistic maps
- ◆ Weak coarse grained (symbolic dynamic) coupling between lattice sites
- ◆ Alternate between chaotic logistic and fixed point dynamics

Observe: dynamics of emergent domains of informational stability.





- ◆ Origin of life: transition from chemical kinetics to chemically encoded evolution (pre-RNA / DNA code?)
- ◆ Transition to multicellularity [cf. Smith, Laneuville, Guttenberg]
- ◆ Ecological niche formation
- ◆ Evolution of cognitive mechanisms [cf. Wolf, neurological dynamics]