Artificial Life & Complex Systems

Lecture 16

Epilogue

June 9, 2007

Max Lungarella

Artificial Life: Epilogue

"Artificial Life is the study of man-made systems that exhibit behaviors characteristic of natural living system. It complements the traditional biological sciences concerned with the analysis of living organisms by attempting to synthesize life-like behavior within computers and other artificial media. By extending the empirical foundation upon which biology is based beyond the carbon-chain life that has evolved on Earth, Artificial Life can contribute to theoretical biology by locating life-as-we-know-it within the larger picture of life-as-it-could-be." *(Langton, 1989)*

Artificial Life 2: Epilogue

Artificial Life is about the synthetic study of complex adaptive (life-like) systems (natural and artificial ones). The goal is not only to provide biological models but also to investigate general principles of life.

Artificial Life: Epilogue

Traditional biology (Science, in general) is analytic and top-down: starts from the top (e.g. organism level) and seeks for explanations in terms of lower level entities

Artificial life is synthetic and bottom up: starts at the bottom (e.g. molecular level) and works its way by synthesizing complex systems from many simple interacting entities

Artificial Life: Epilogue

Artificial life studies life-as-it-is and as-it-might-be

Artificial Life is:

- Artifactual (man-made), but *not* unreal
- Bottom-up, not top-down
- Synthetic, not analytical
  - Top-down analysis informs and tests Alife research. But bottom-up synthesis plays a larger role than in more traditional sciences (synthetic methodology)
- Leverages *emergence*

Goals:

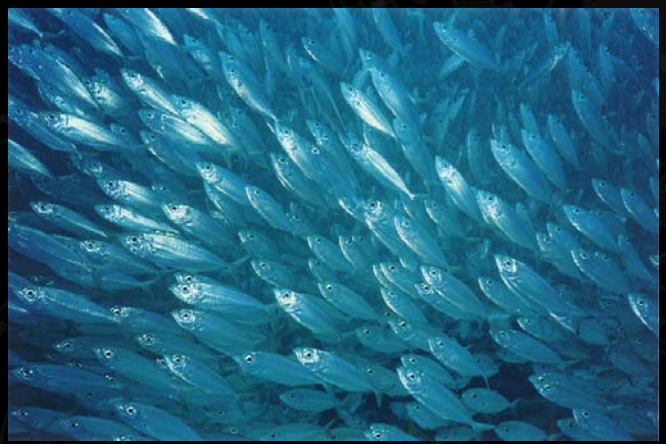
1) **understand complex adaptive (living) systems** – e.g., brains, organisms, insect colonies, ecosystems, economies, etc.
2) **use principles derived from this study to design new, successful complex adaptive systems** – e.g., self-configuring robots, smart structures, swarms of unmanned vehicles, self-organized networks, etc.

Epilogue: Pattern Formation

Pattern = organized arrangement of objects in space and time

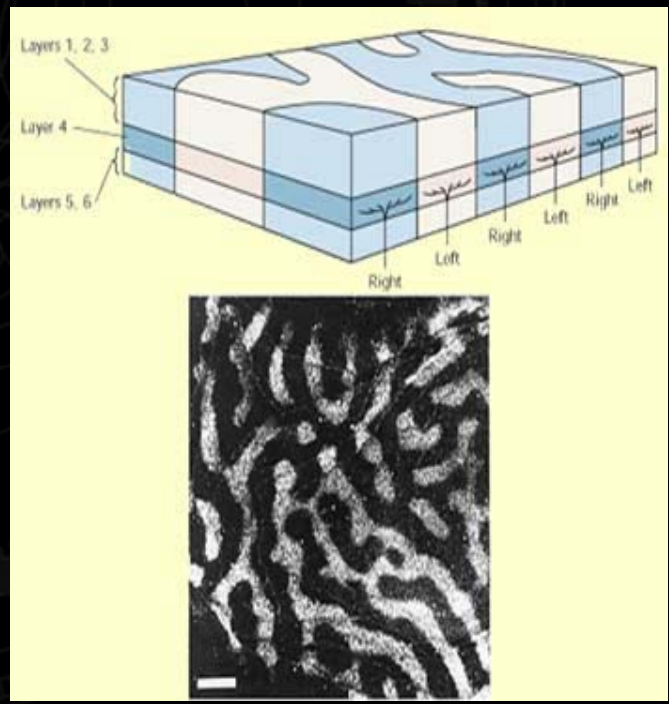
Examples of biological patterns:

- Schools of fish
- Raiding column of army ants
- Ocular dominance stripes in visual cortex
- Synchronous flashing of fireflies
- Pigmentation patterns on shells



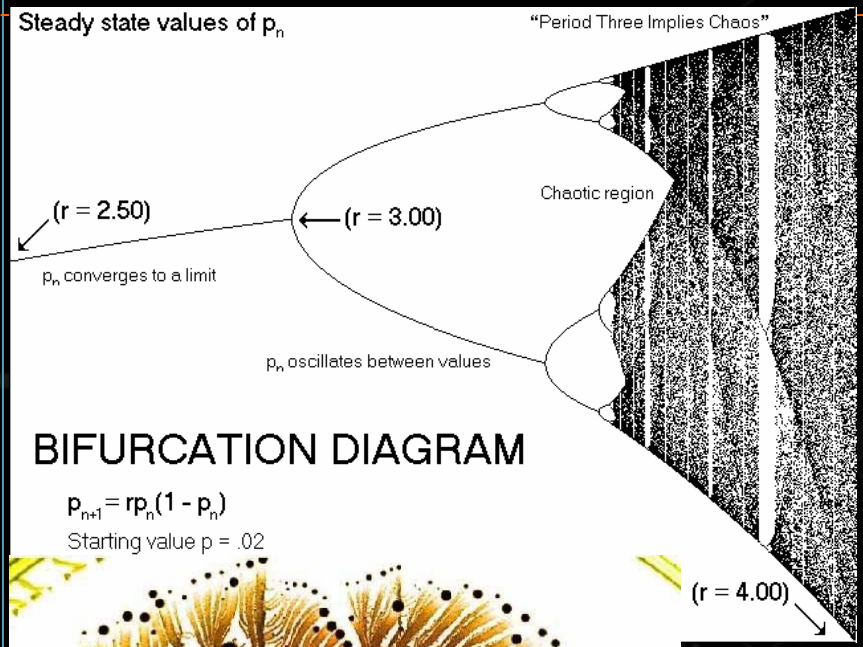
school of fish

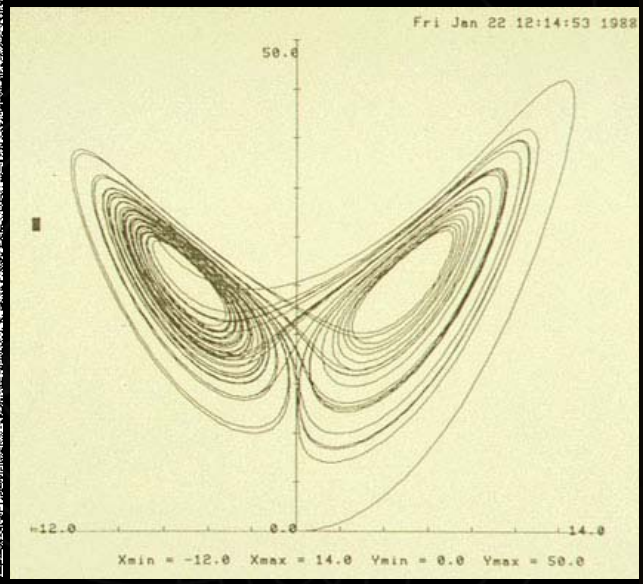
fireflies

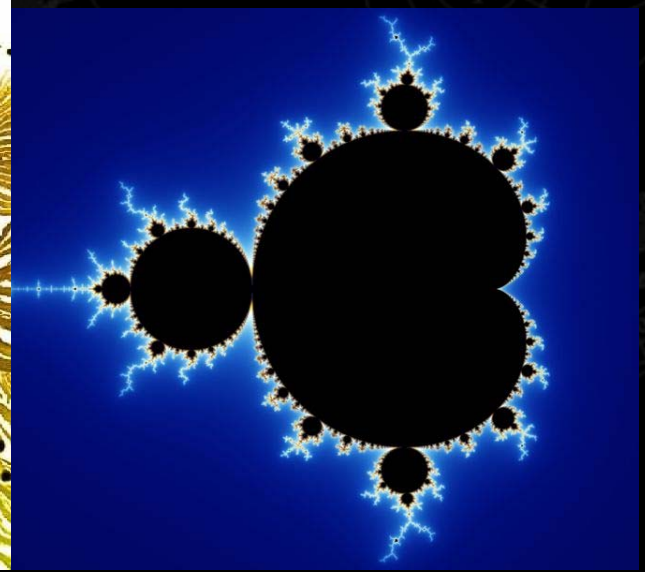


inputs from left eye (black) and right eye (white)

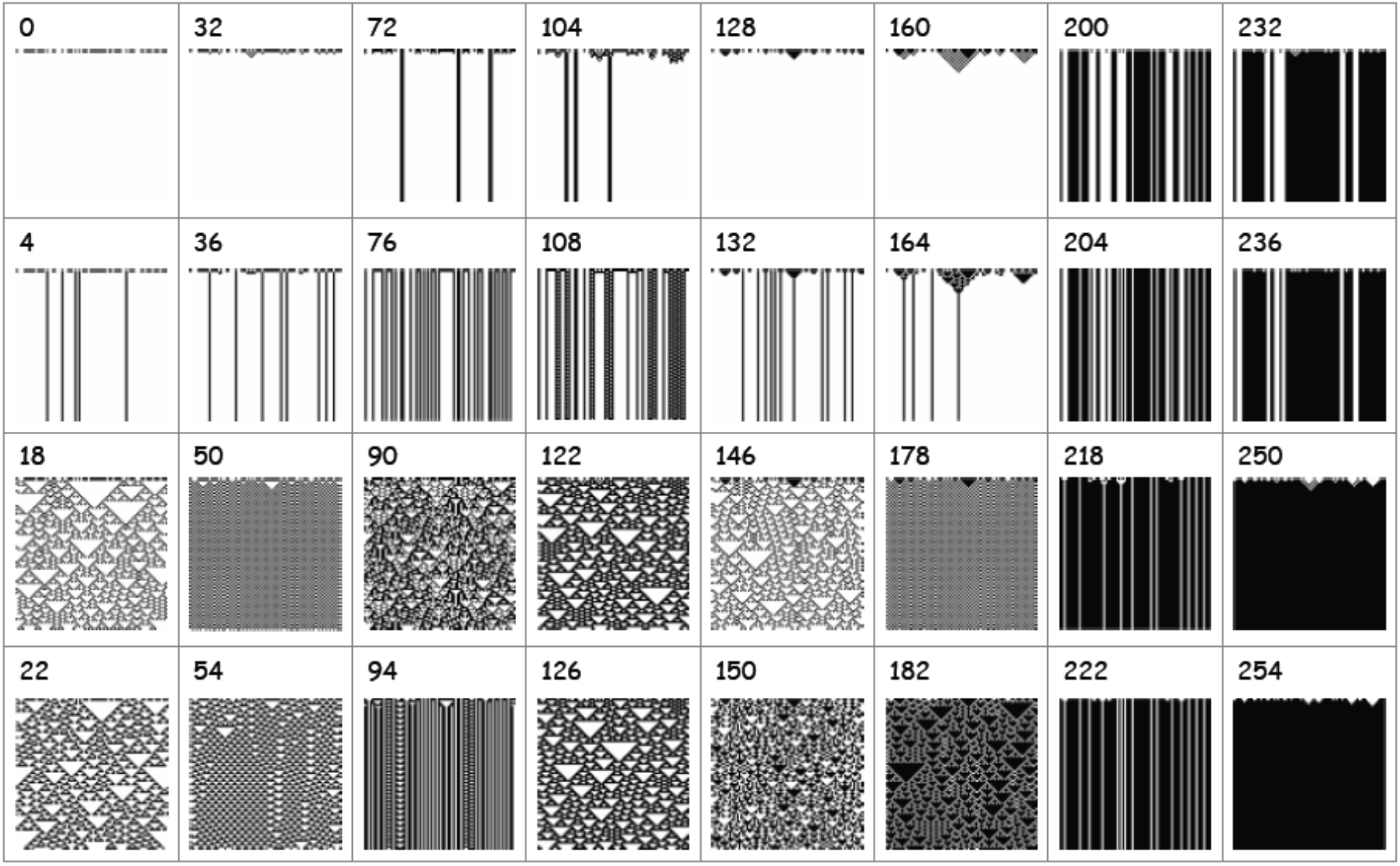
Epilogue: Dynamical Systems



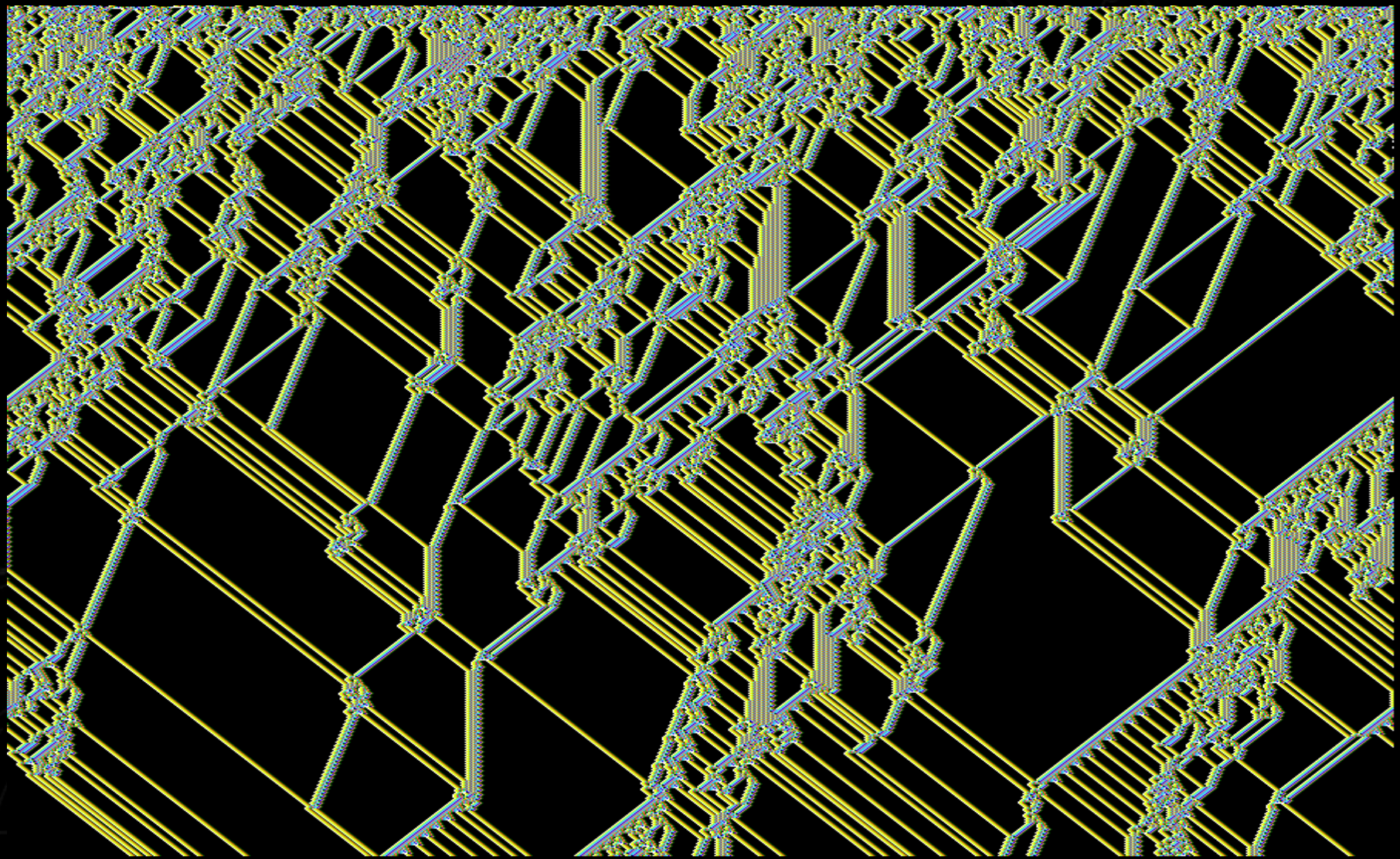




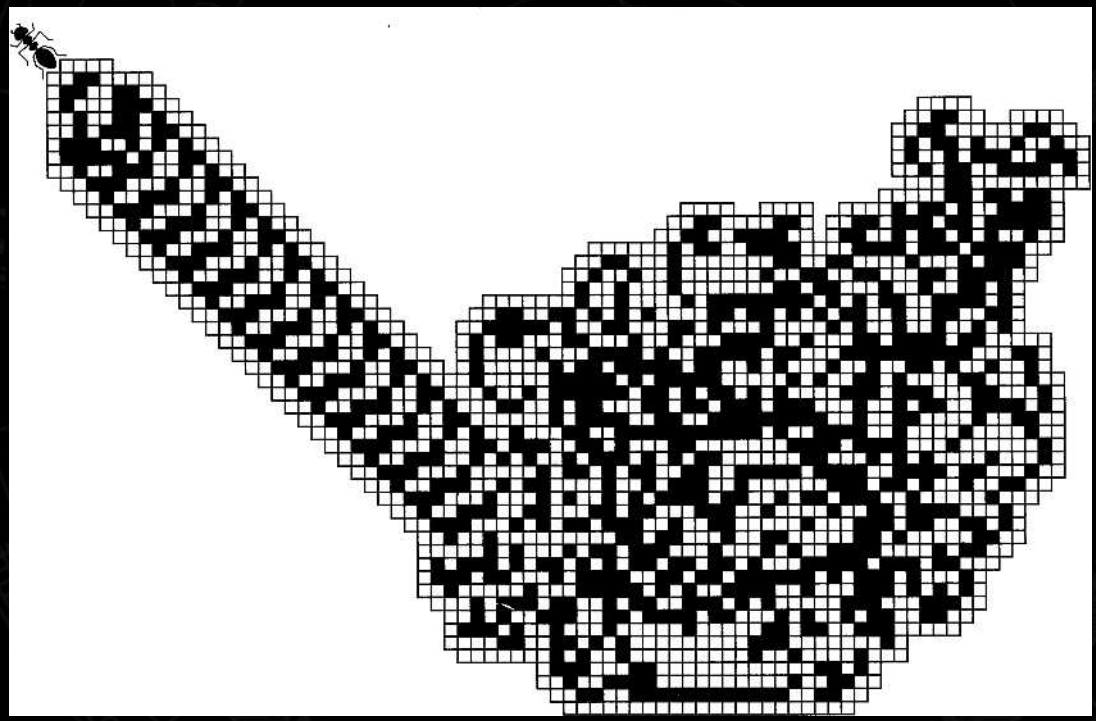
Epilogue: Cellular Automata



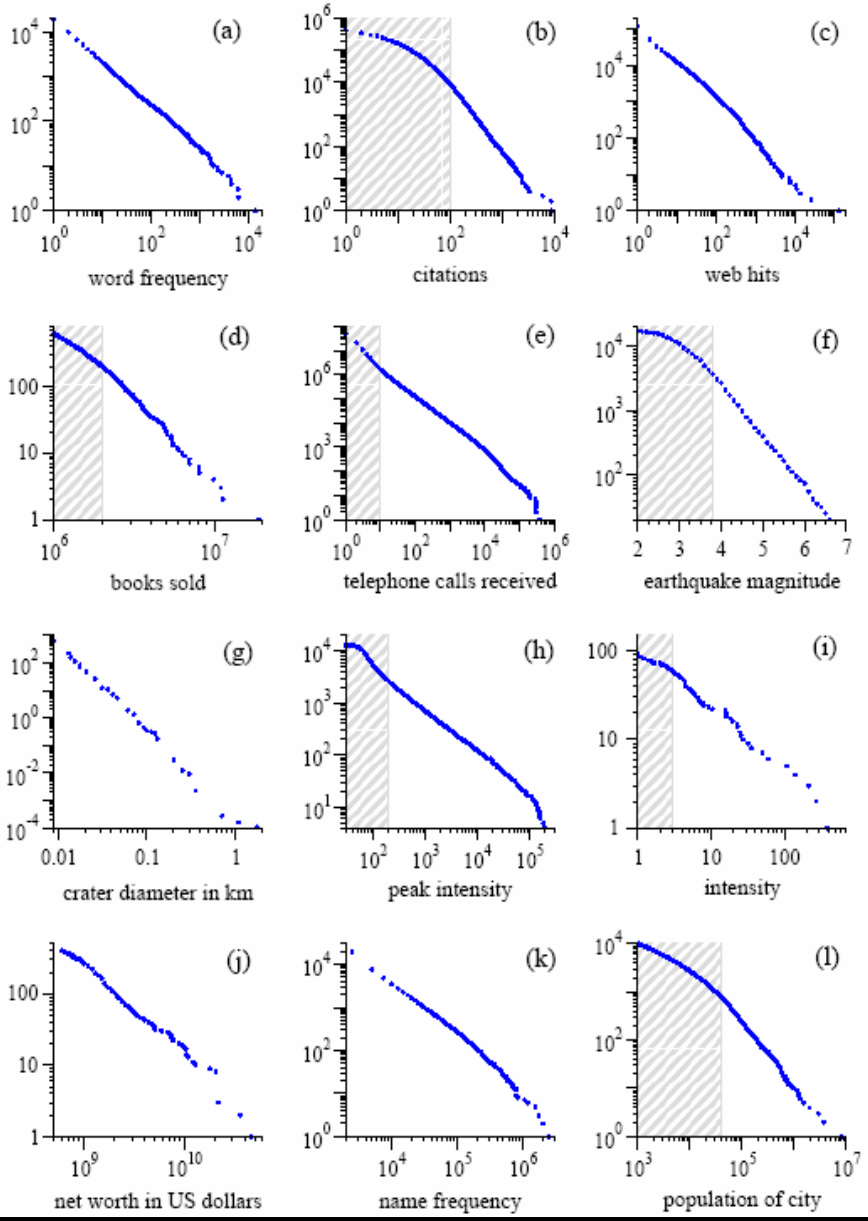
Epilogue: Cellular Automata

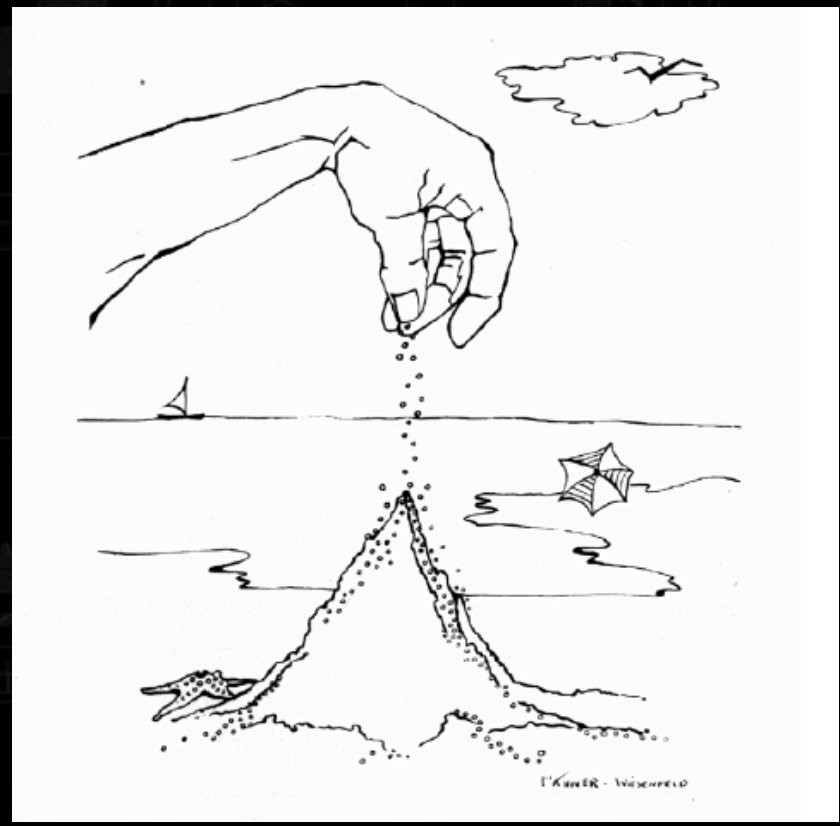


Epilogue: Cellular Automata

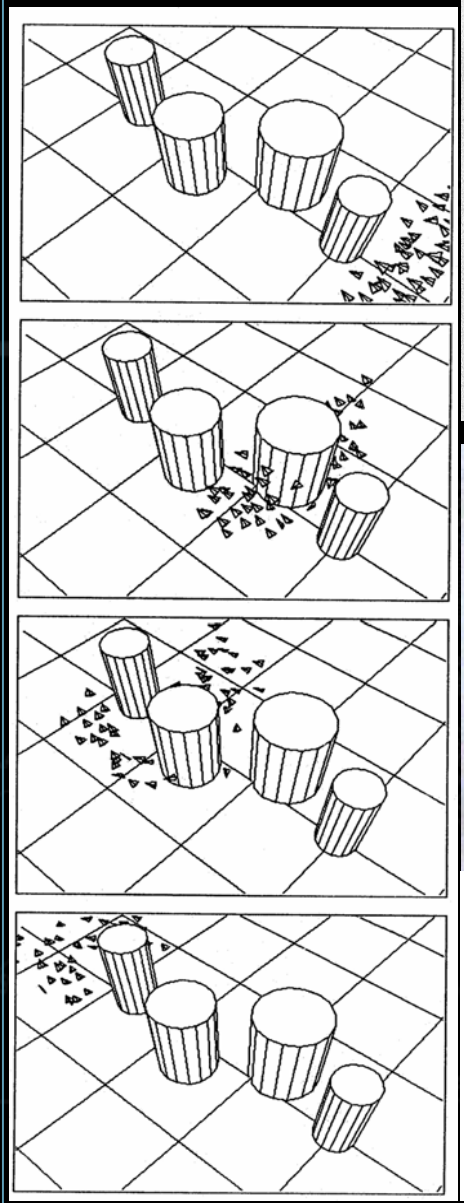


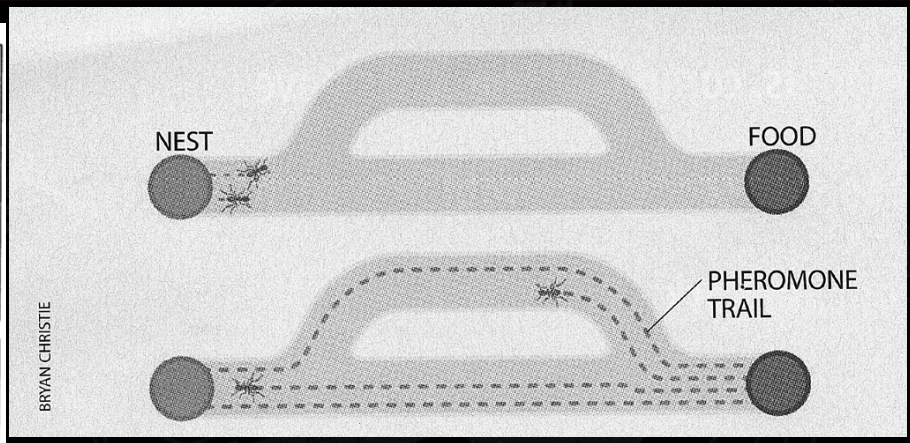
Epilogue: Power Laws and Sanpiles

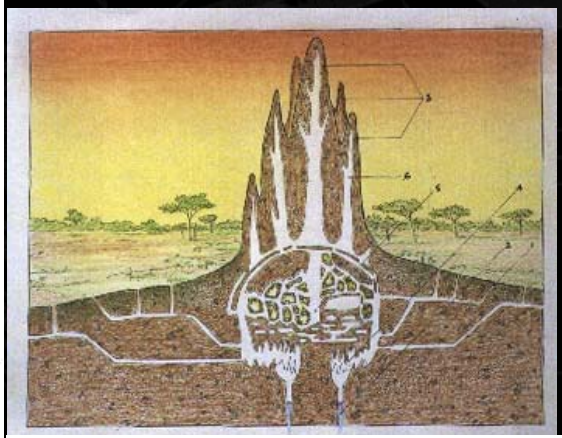


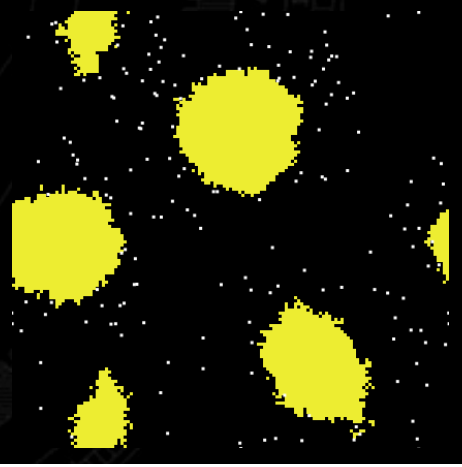


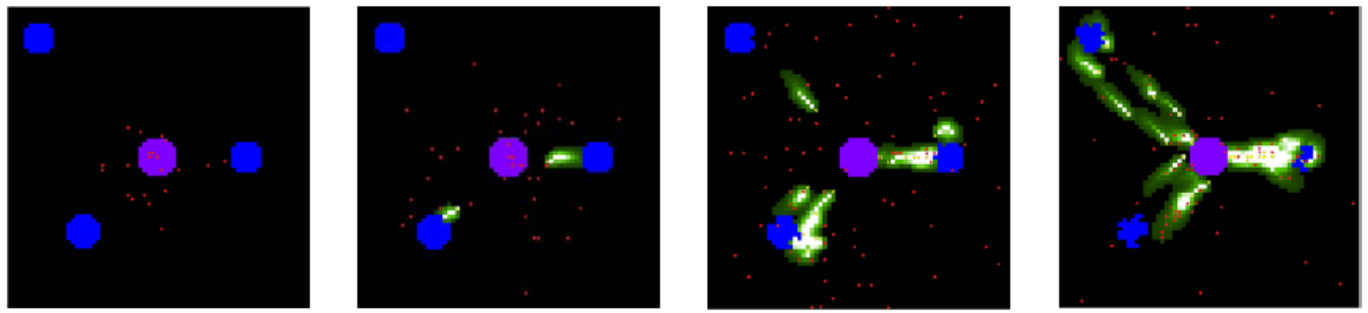
Epilogue: Swarms and Collective Intelligence



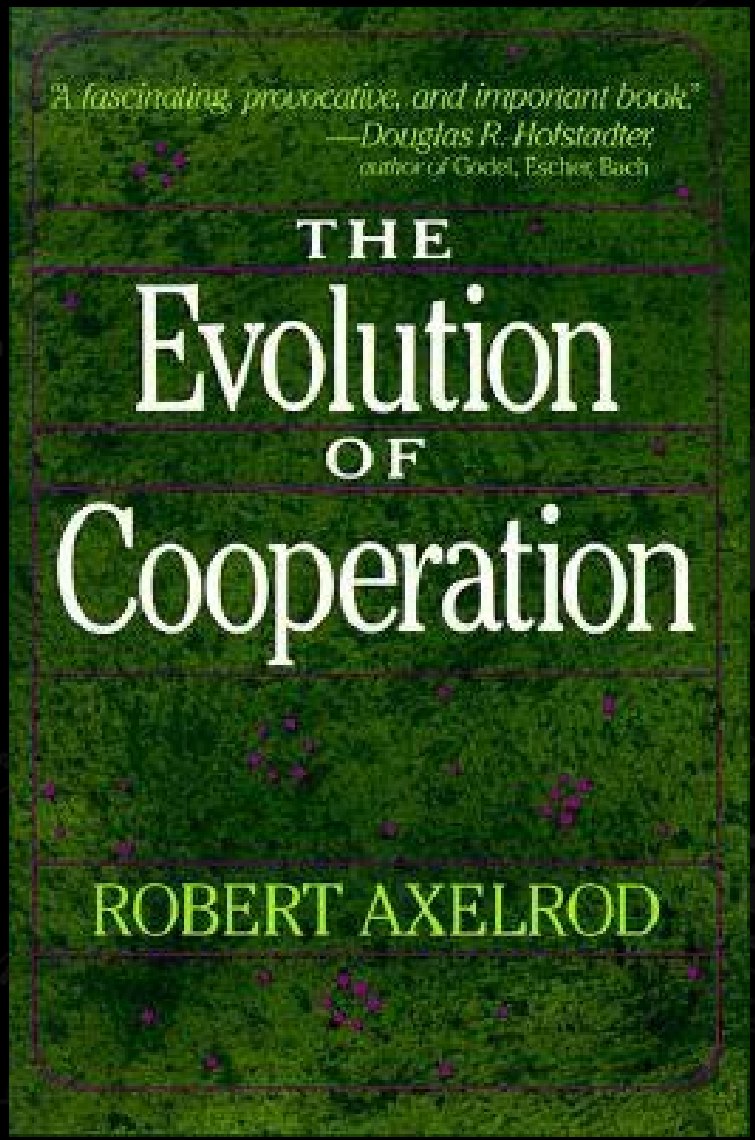


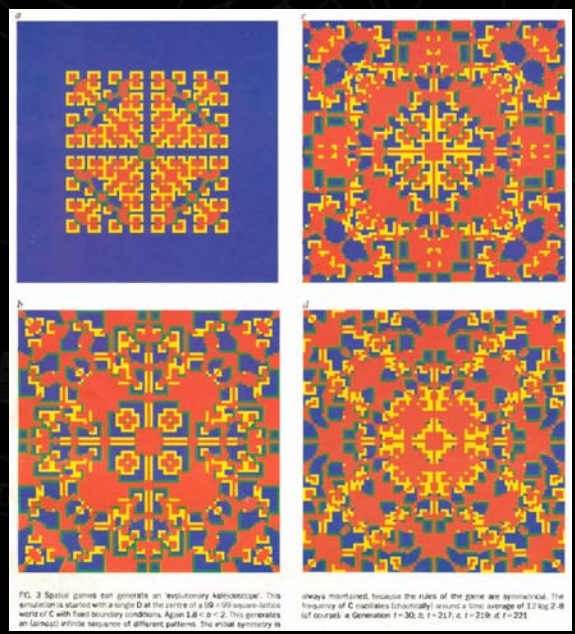






Epilogue: Evolution of Cooperation





Epilogue: Artificial Societies

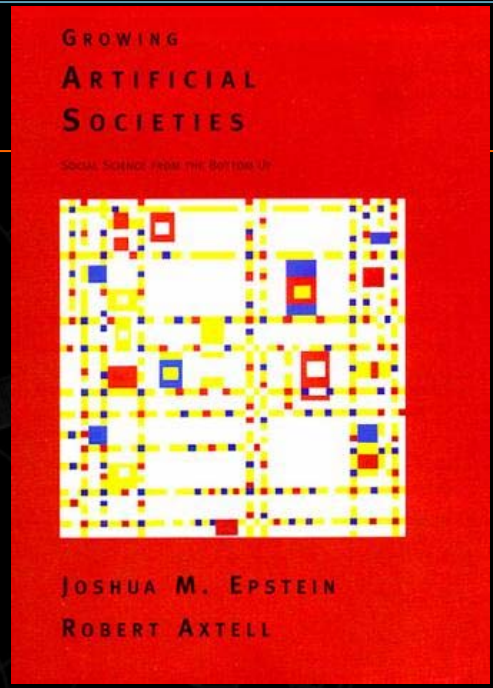
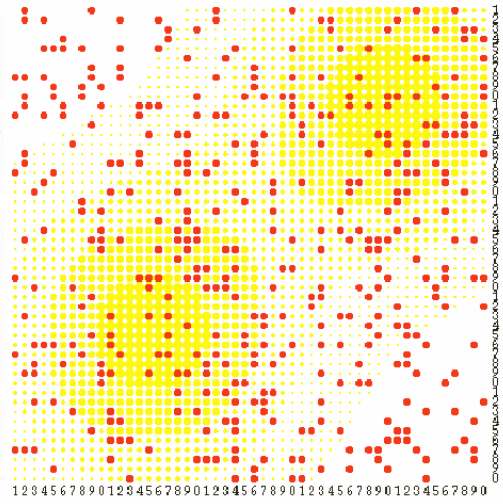
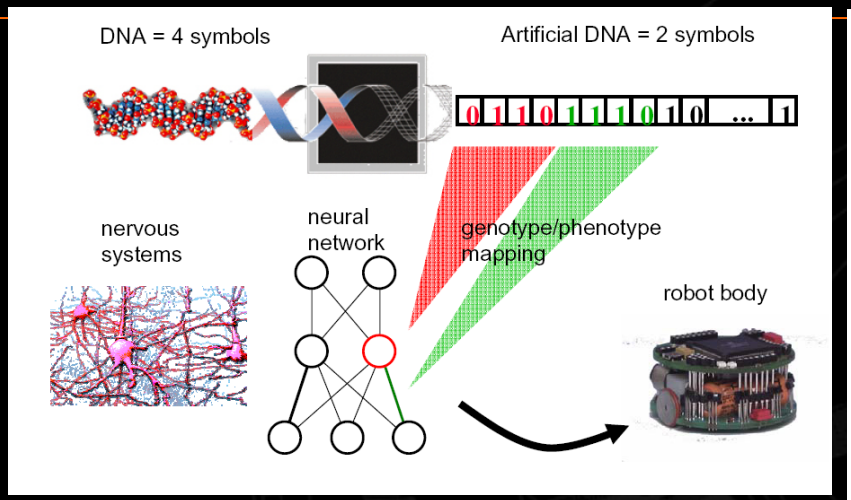


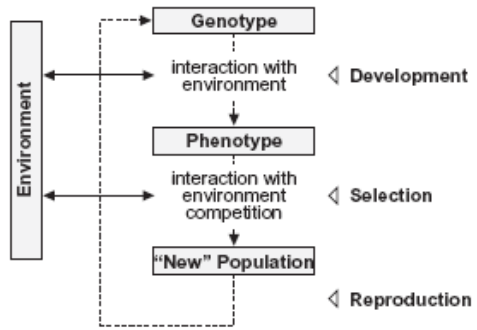
Figure II-2. Sugarscape with Agents



Epilogue: Artificial Evolution



a.



b.

encoding	development	selection	reproduction
• binary • many-character • real-valued	• no development (phenotype = genotype) • development with	• "roulette wheel" • elitism • rank selection • tournament • truncation • steady-state	• mutation • crossover

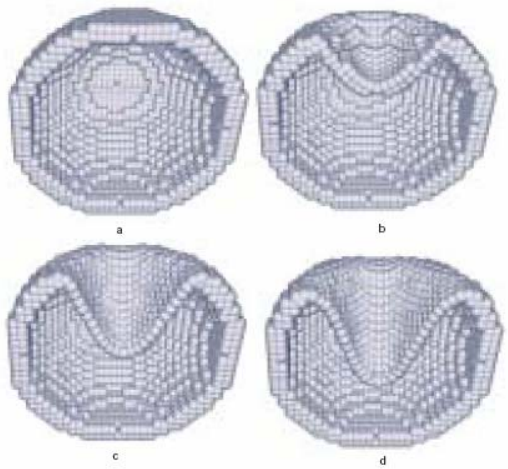
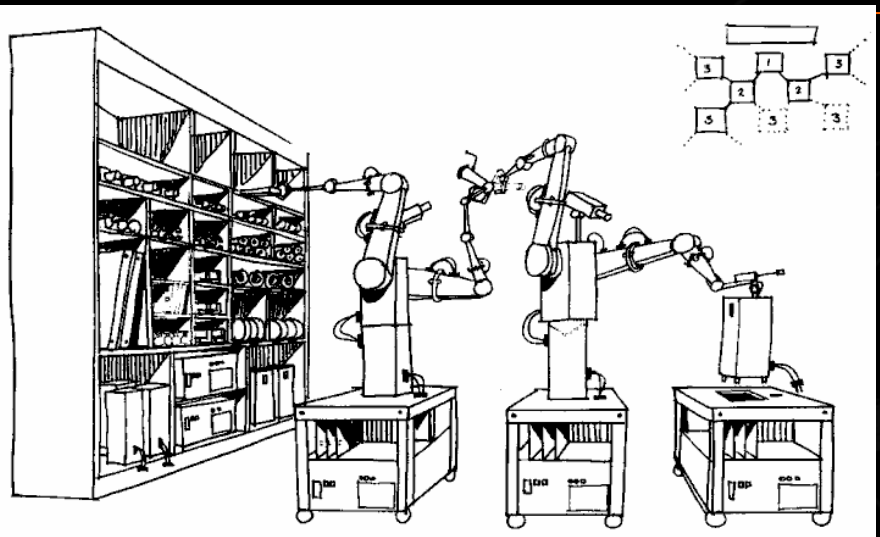


Figure 7: Four stages of simulated invagination. Cells were positioned spherically and the task was to evolve a mechanism able to invaginate a part of the sphere as illustrated in the above sequence of the dynamics of this developmental process.

Epilogue: Self-Replication



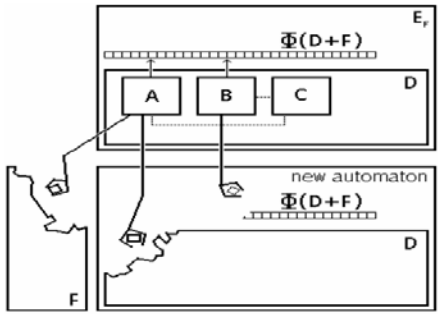


Figure 2: *Schematic view of von Neumann's theoretical self-replicating machine. A: general construction machine; B: general copying machine; C: control machine.*

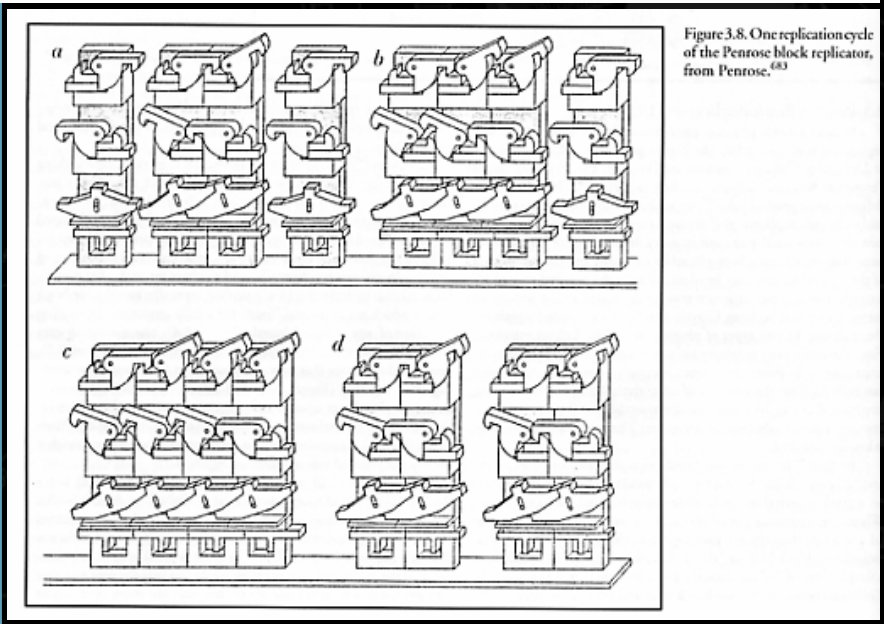
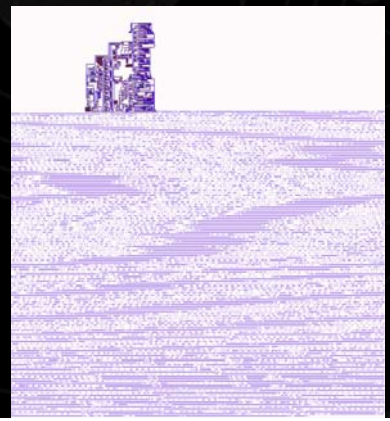
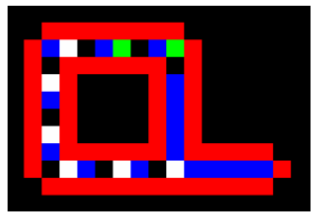


Figure 3.8. One replication cycle of the Penrose block replicator, from Penrose.[83]





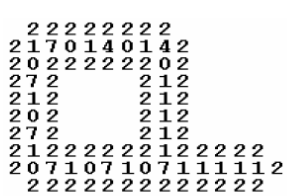
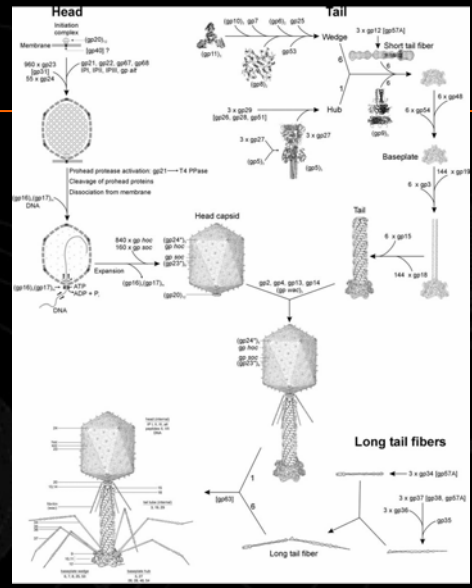
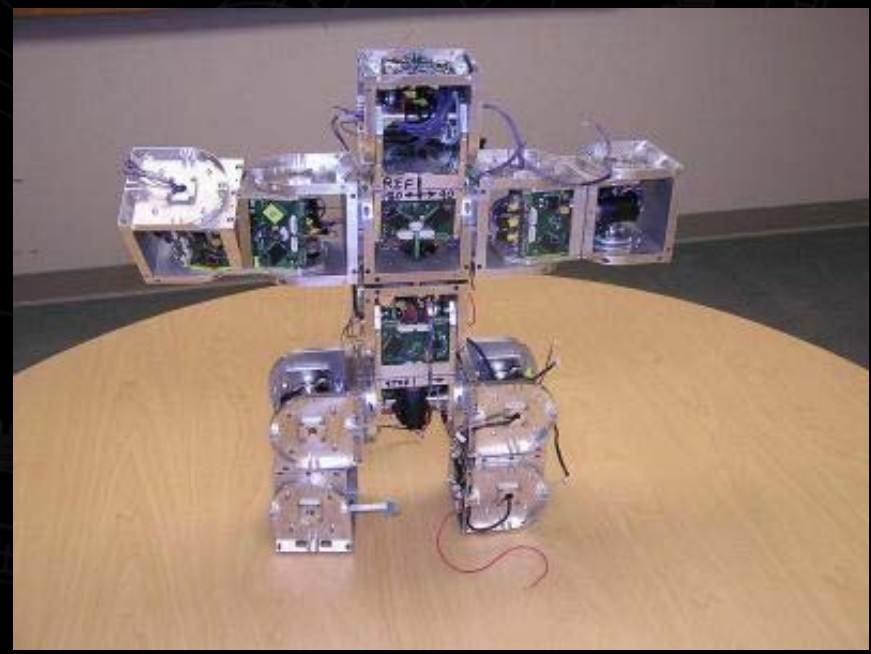


Figure 4: *Initial configuration of a Langton Loop. Note the red "sheath" (state 2) that protects the flowing information. The data flows round the loop anti-clockwise. It is copied at the junction of the arm and one copy is sent round the loop, to keep the structure "alive", and the other copy is sent down the arm to be interpreted into extending and bending it.*

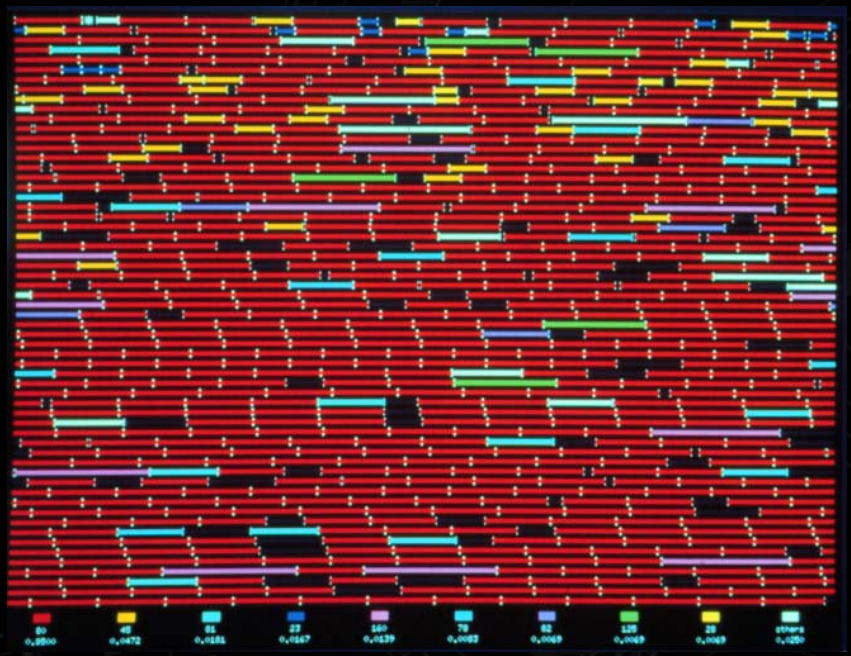
Epilogue: Self-Assembly

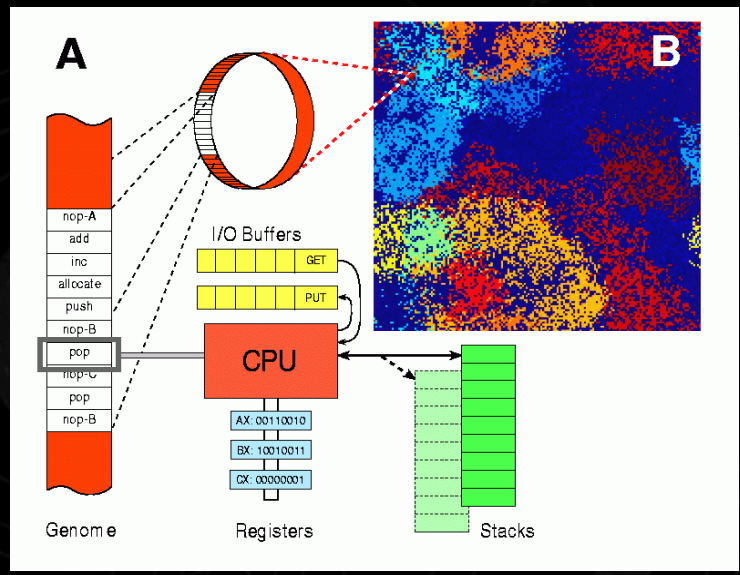
Fig. 1. Four programmable parts partially assembled into a triangle. The parts bind upon random collisions and communicate via IR, deciding whether to remain bound or to detach. A graph grammar stored on the microcontroller of each part determines the ultimate global structure that will emerge. The parts are not self-motive but instead are "mixed" on an air table by overhead oscillating fans.





Epilogue: Computational Ecologies





The End