New Approaches to Self-Assembly

John Rieffel

Brandeis University DEMO Lab

Motivation

Brooks:

Single-cell entities arose out of the primordial soup roughly 3.5 billion years ago. A billion years passed before photosynthetic plants appeared. After almost another billion and a half years, around 550 million years ago, the first fish and Vertebrates arrived, and then insects 450 million years ago. Then things started moving fast. Reptiles arrived 370 million years ago, followed by dinosaurs at 330 and mammals at 250 million years ago. The first primates appeared 120 million years ago and the immediate predecessors to the great apes a mere 18 million years ago. Man arrived in roughly his present form 2.5 million years ago.

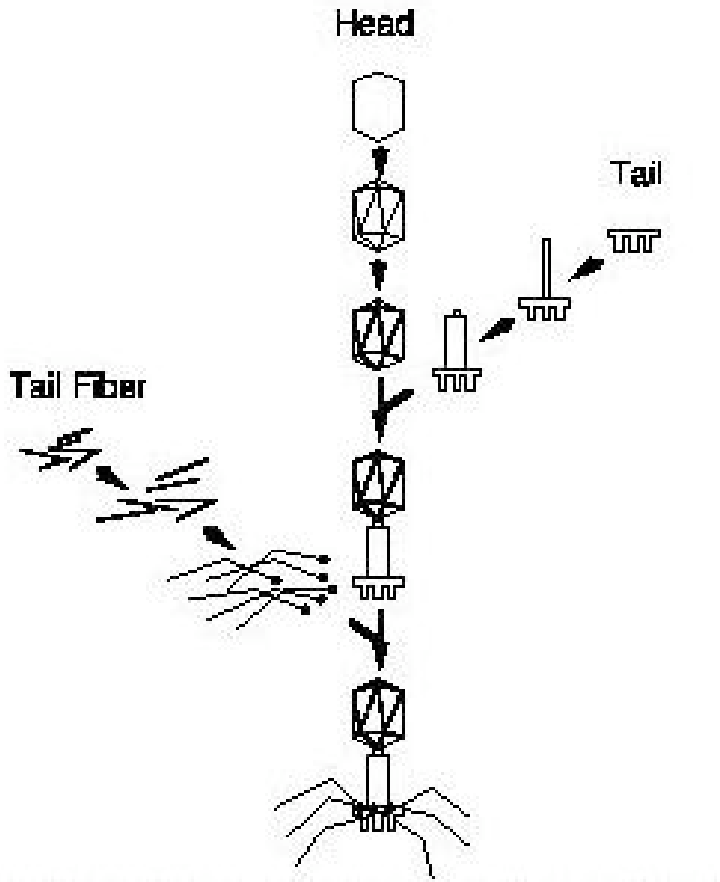
...This suggests that problem solving behavior, language, expert knowledge and application, and reason, ***are all pretty simple once the essence of being and reacting are available****. That essence is the ability to move around in a dynamic environment, sensing the surroundings to a degree sufficient to achieve the necessary maintenance of life and reproduction. This part of intelligence is where evolution has concentrated its time it is much harder.*

Essentially: Get the basics right first

Simple

- Dog? Insect? Fish? No.
- Bacteriophage? Virus? Maybe
- Some interesting properties of viruses…

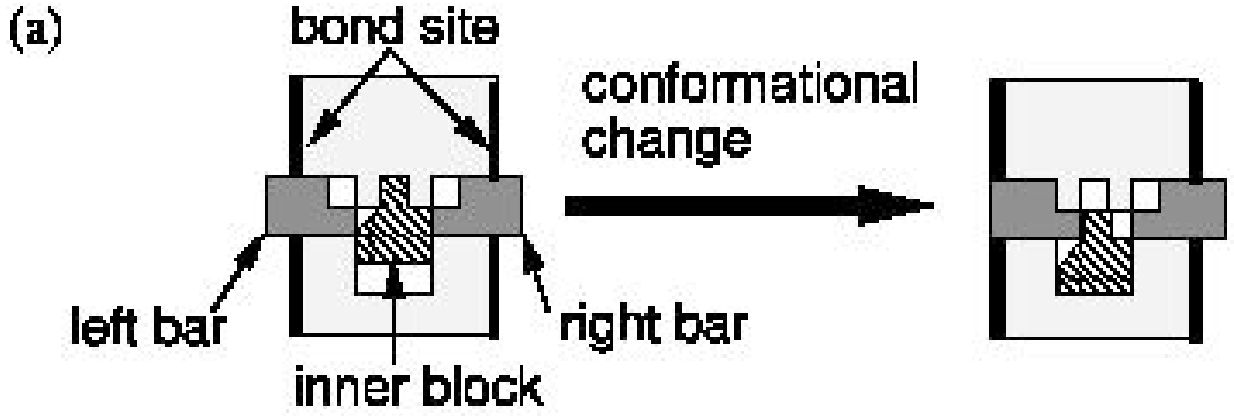
Spontaneous Self-Assembly



- Subcomponents assemble **<u>in order</u>**
- How to create order during *random* assembly?
  - conformational switching

Conformational Switches (Jakiela & Saitou)

- as sub-components are assembled, shape changes to allow/deny new bonds.



Conformational Switches: Advantages:

- Allow for “randomized assembly”
  - add parts to “vat”, and stir
- Allow creation of stable sub-assemblies
  - (we know those are important, cf. Hora & Tempus - Simon, also Watson)
- Subassemblies can have temporary components (i.e. scaffolding)
  - remove themselves during assembly.

Think Simpler:

- Cellular Machinery
  - proteins built from amino acids
  - proteins “building” proteins
  - proteins as templates for proteins

Interlude

- Tie-Ins
  - Algorithmic Chemistry, autocatalytic cycles
  - Modular Robots
    - reconfigurable robots
    - self assembling robots
    - self reproducing robots
  - Embodied Evolution
  - Swarm Intelligence

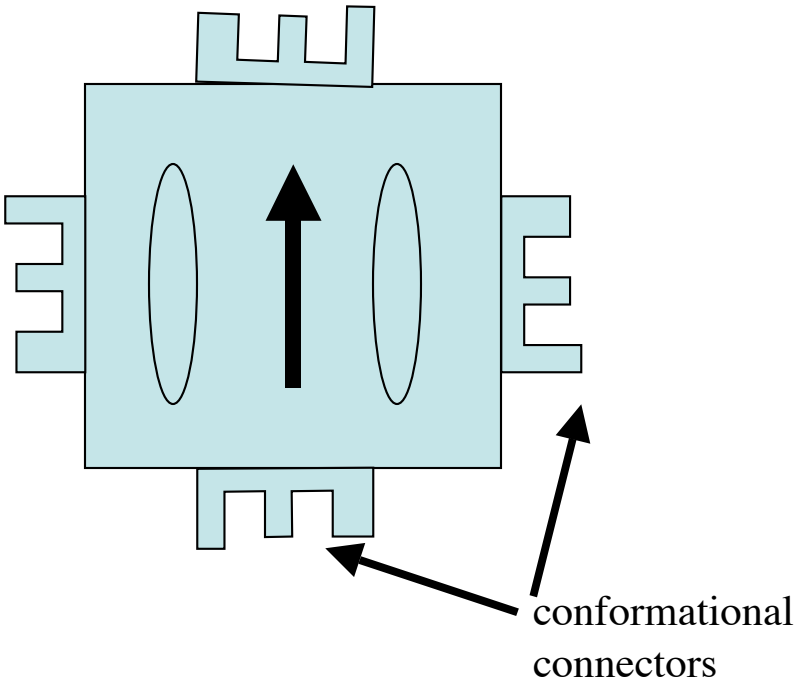
Related Work

- Saitou & Jakiela
  - simulations of 1-d and 2-d assemblies
  - use conformational switches on parts to maximize **yield** of final assembly
  - “genetic search” for parts to maximize yield
- Hosokawa, Shimoyama, Miura
  - real 2-d mechanical parts,
  - but, by nature, fixed rules

Imagine:

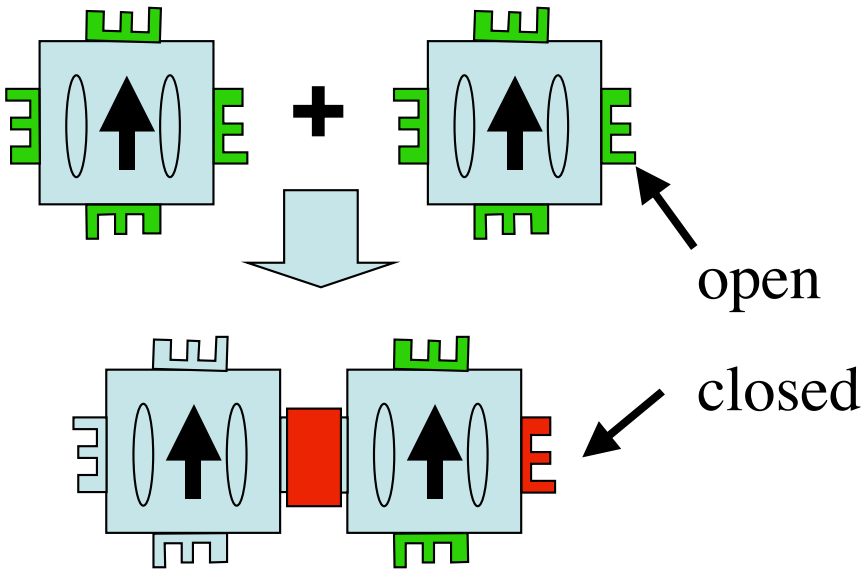
- Real parts, capable of 2-d connections
  - (hosokawa et al)
- **dynamic** conformational switches
  - search for rulesets which maximize some behavior
- search need not be genetic

robotic amino acids?



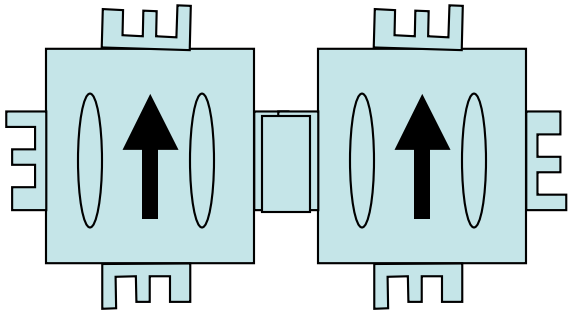
- Imagine:
  - simple robotic element
  - can only move forwards
  - can join other elements
    - via confomational conenctors
  - trying to maximize:
    - distance covered?
    - speed?
  - but with obstacles, walls, etc can't do it alone

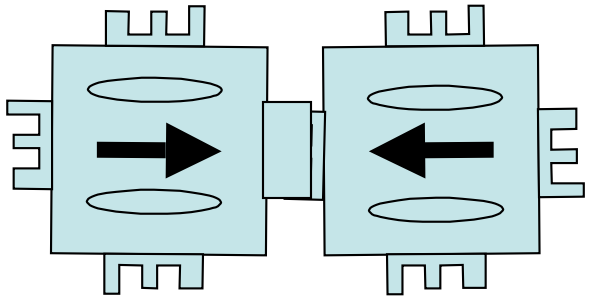
robotic amino acids: conformational bonding sites

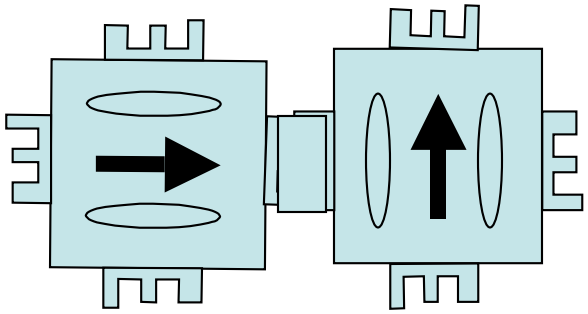


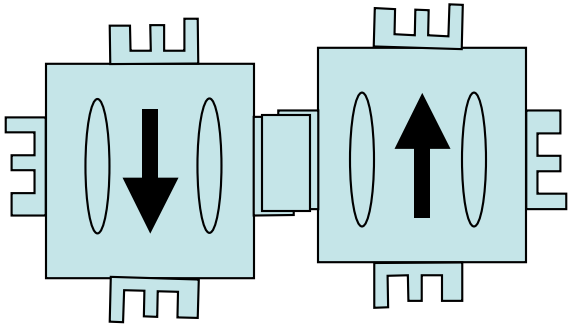
- Joining other elements:
  - connectors are “conformational”
  - element contains rule set
    - whether to connect to other elements
  - rule set modified by bonds

robotic amino acids...

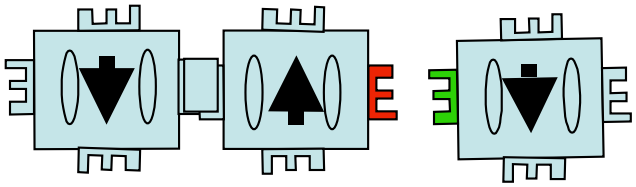




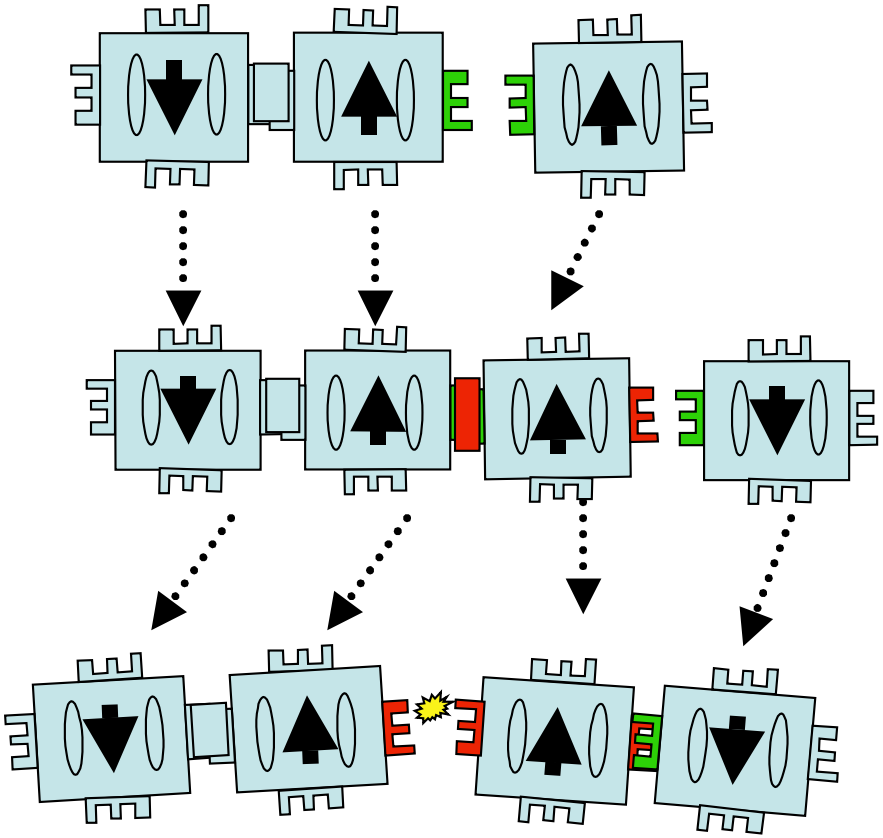




Self Assembly...



Don’t want to connect

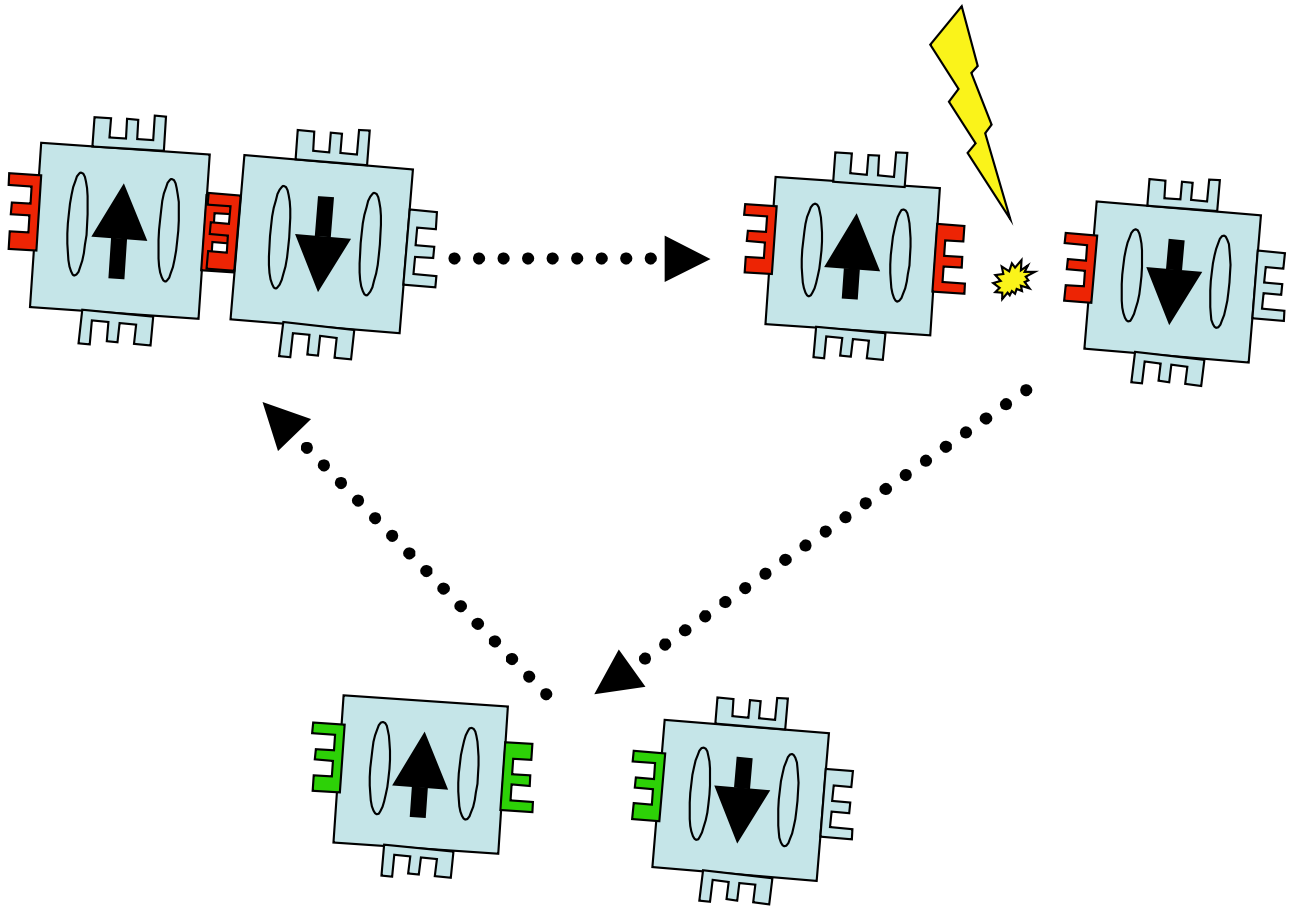


okay to connect...

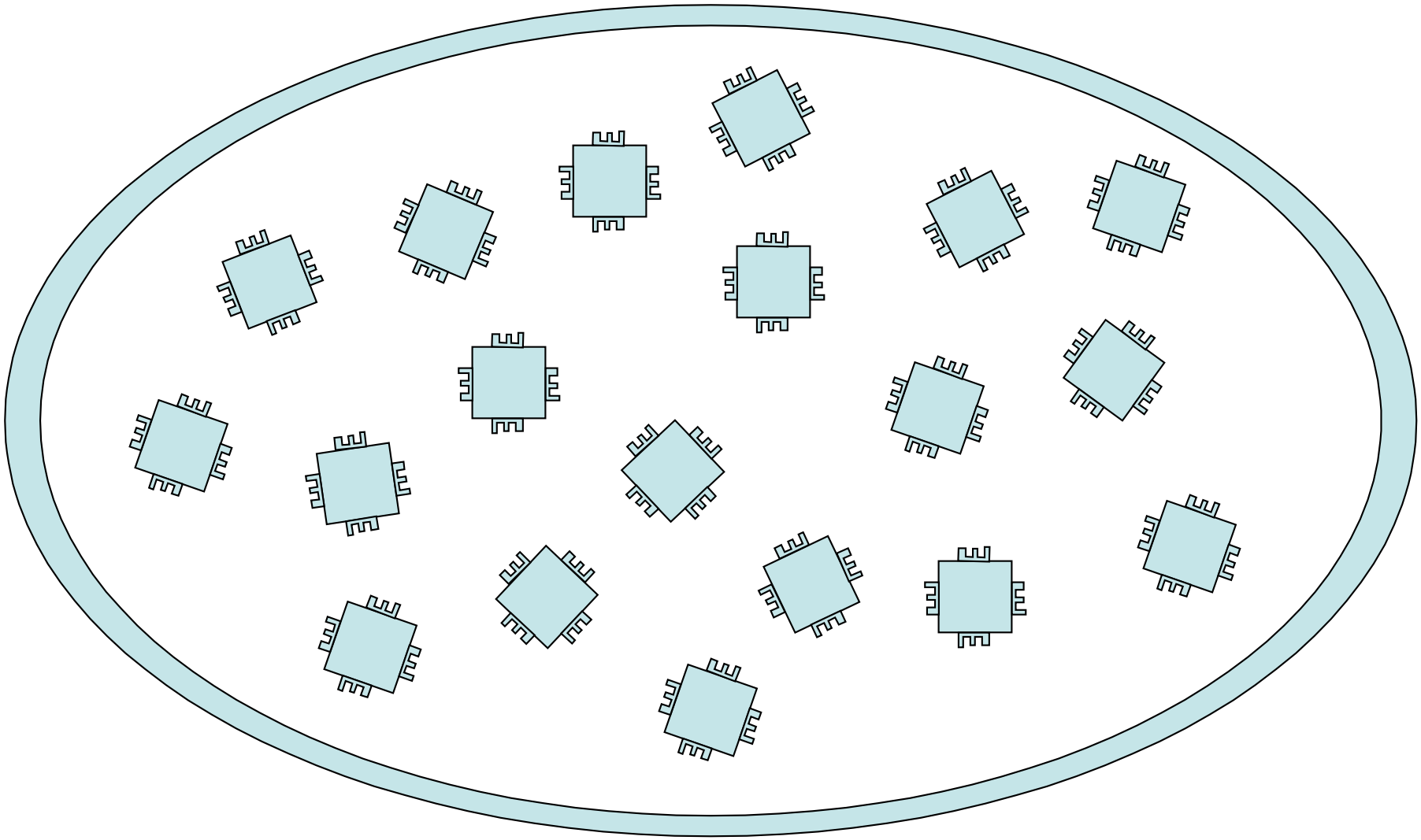
but now what?

one option...

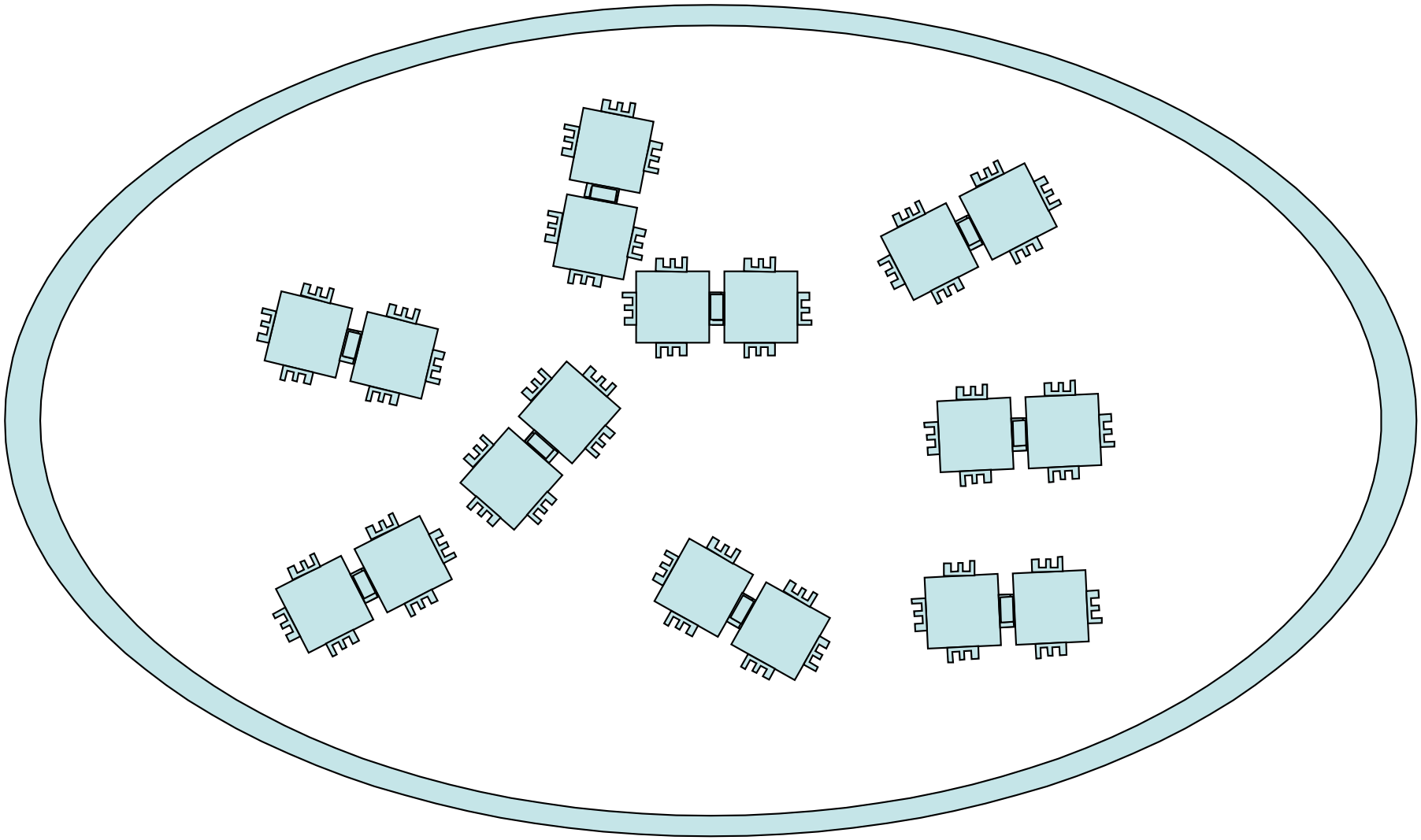
Self Repair...



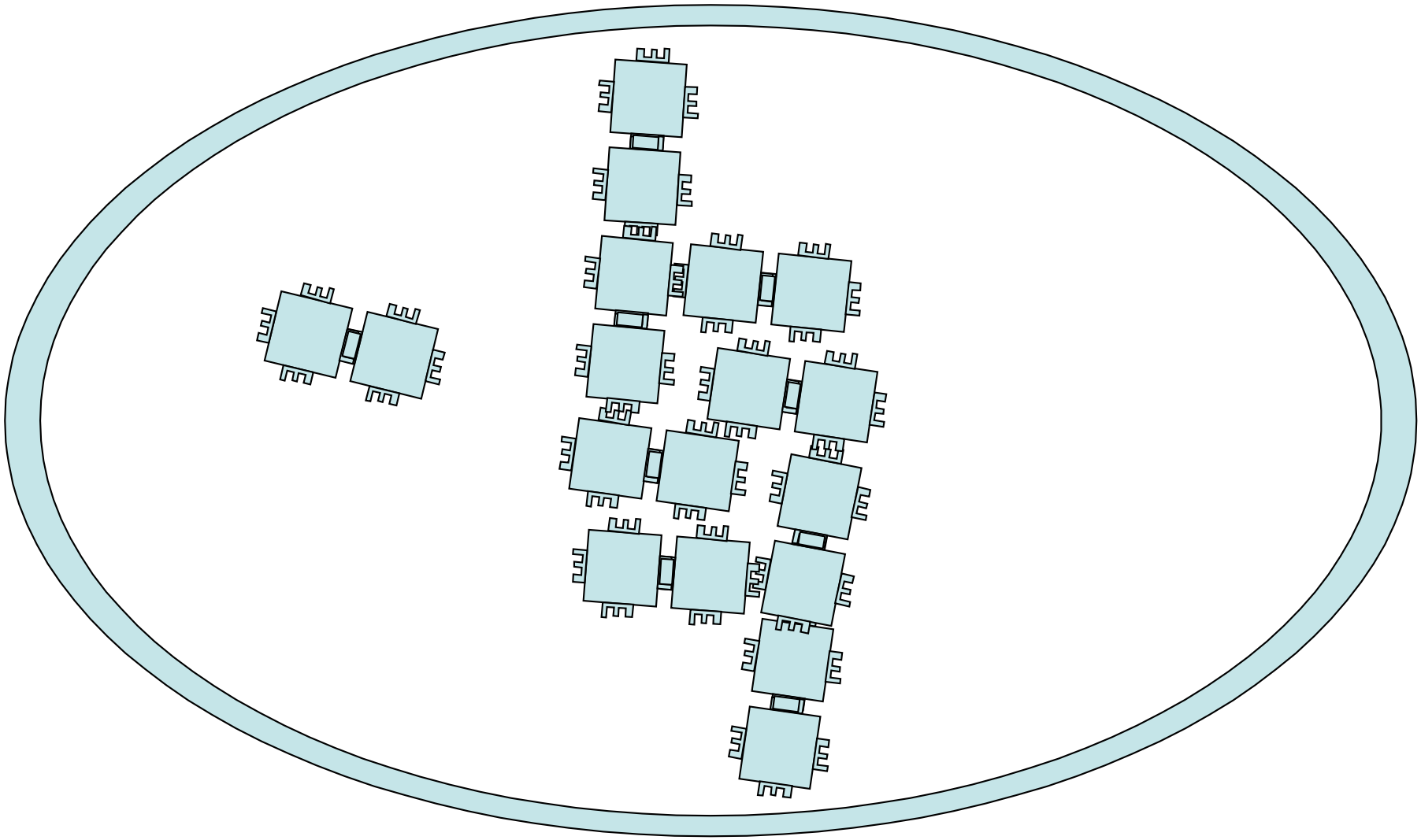
robotic amino acids...



...forming stable pairs



... and building proteins (which build proteins)



What I want to do:

- Simulate 2-d (SWARM?)
  - look for good results
    - autocatalytic cycles, self-assembly/repair
    - interesting rule sets
    - role between “density” of parts, size of enclosure
- Embody in actual robots
  - very small, very simple
  - really an extension of embodied evolution