

# THE FACTOR 10 CHALLENGE

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# Metaphors of Cognition

Computers have been the metaphor of cognition for 50 years

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Robots have become the new metaphor over the last 10 years



# Typical Robot is:

Designed for specific goal

Assembled by human/machine

Kept alive by batteries

Hardware + Software

Conventional hardware

On/off switch



# Most Living Organisms:



Self-assemble and grow

Interact with environment

Find own energy / metabolism

No brain/mind dichotomy

Soft, compliant, self-healing

Die only once



## Factor 10

Fully functional physical artifacts (not simulations), which, during an extended but limited period of time (e.g., 10 months) autonomously grow:

- Cognitive abilities (IQ and sensorimotor behaviors) by at least a factor of 10;
- Body volume, thereby differentiating out organs and effectors, by at least a factor of 10



# Type I artifacts

Artifacts evolving their cognition and motor control autonomously based on multimodal/multisensory feedback in a predefined and fixed body

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## SOME BIG CHALLENGES:

- Open-ended, online, continuous adaptation
- Architectures
- Self-assessment of performance



# Type II artifacts

Artifacts with bodies/effectors that flexibly adapt their shapes to different tasks:

- modular systems of basic elements that re-organize their structure
- robots made of materials with mechanical plasticity and a peripheral nervous system



# Self-assembling robots

Molecule robot, Dartmouth College

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Polybot, Xerox Parc

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M-Tran, AIST/Tokyo Inst. Technology

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Conro, USC Information Sciences Inst.

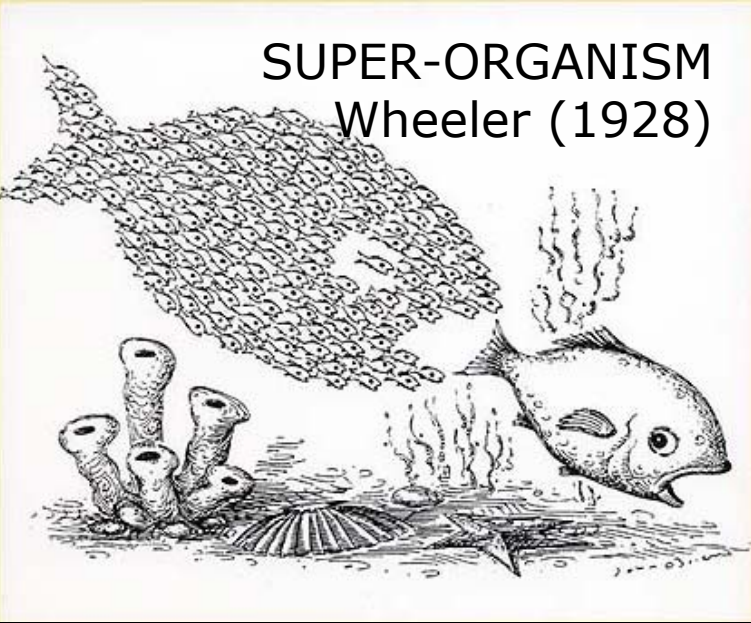
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# Super-organisms

SUPER-ORGANISM  
Wheeler (1928)



# Gel Robot, Univ. Tokyo

- Composite polymers with deformation driven by catalytic reaction in salt water
- Shape and connectivity determine type of motion

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# Type III artifacts

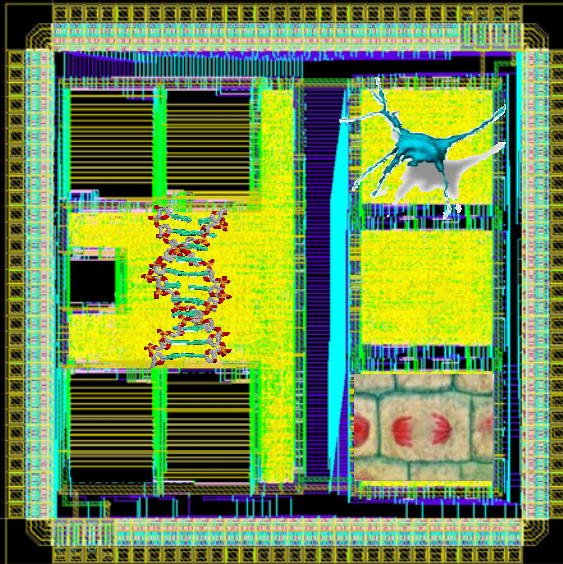
Artifacts that co-evolve their distributed brains and bodies in permanent interaction with the environment over an extended period of their lifetime





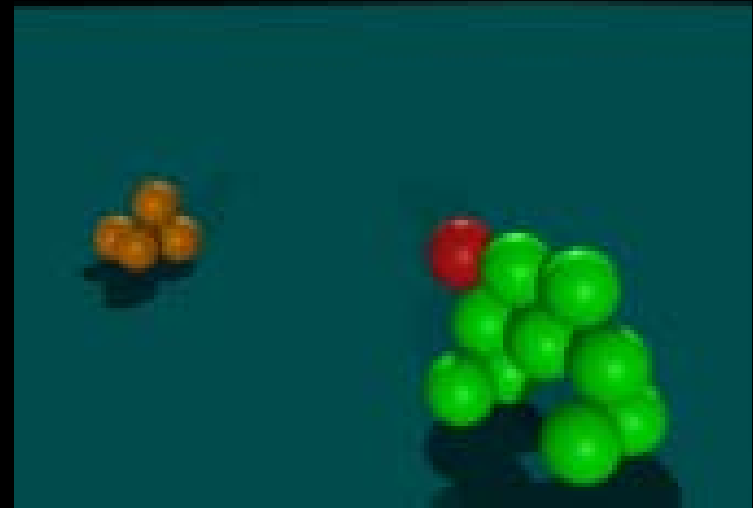
## POETIC TISSUE

A multi-cellular circuit capable of evolution, growth, differentiation, and neural plasticity



## HYDRA

A growing artefact composed of robotic cells capable of evolution, self-assembly, and self-organization



BUT:

Growth is implemented by recruiting of elements  
(New) use of conventional mechatronic technology  
No metabolism



# Electronic Brains

## Neuromorphic

- distributed
- adaptive
- simple

No software/hardware dichotomy

## Organic circuits:

- Flexible, redundant, locally unreliable
- Growing
- Bio-degradable (degradation & death)

Analog vs. digital (digital should be emergent)



# Key points

Open-ended adaptation

Behavioral and energetic autonomy (metabolism)

Multi-cellular (vs. monolithic) systems

Physical growth, reproduction, degradation, death

Collaboration with material science

