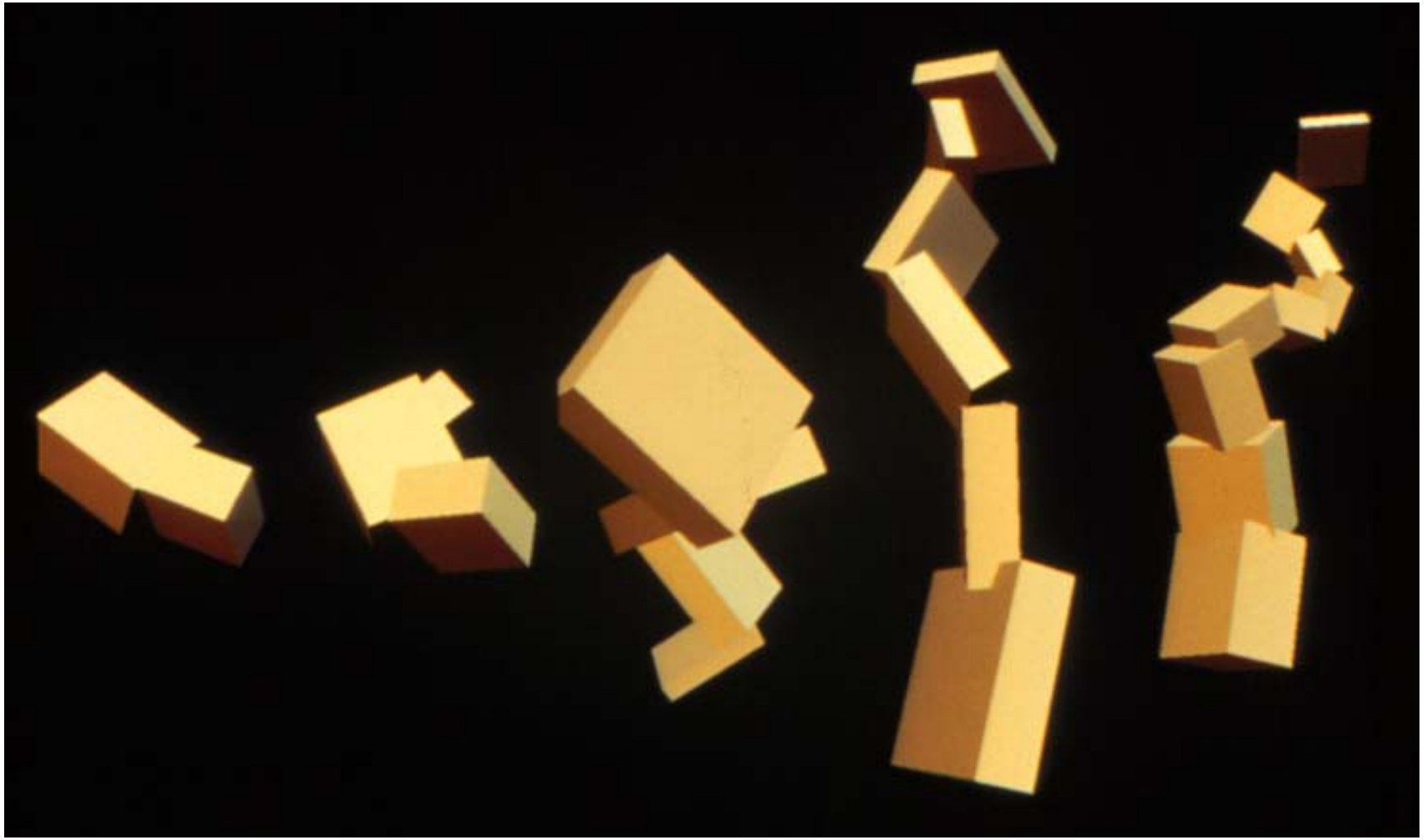
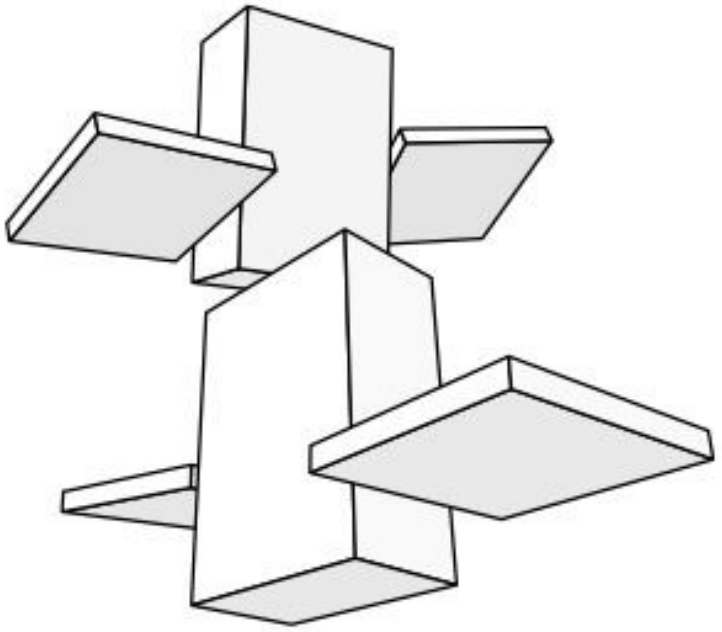
Evolving Virtual Creatures

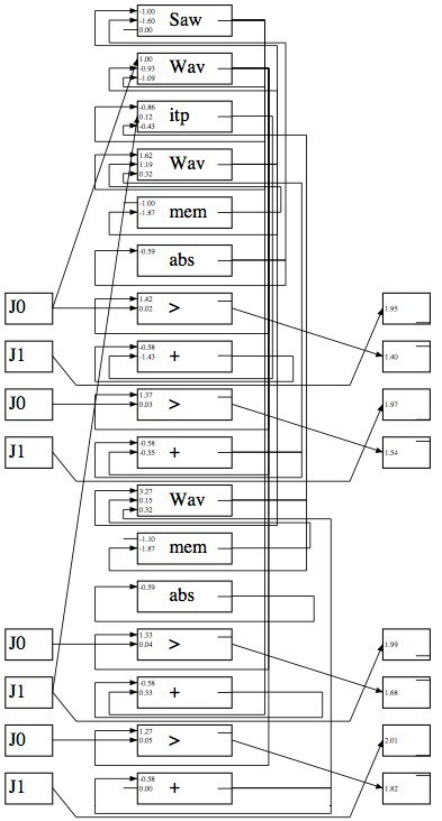
- Karl Sims, “Evolving virtual creatures”, *Proceedings of the SIGGRAPH '94 Conference*, pp. 15-22, 1994



Evolving Virtual Creatures

- Virtual creatures move around in a **3-D simulated world**
- Creatures' **bodies** are rectangular blocks connected by movable joints, with **sensors** for light and proprioception
- Creatures' **brains** are complex neural networks

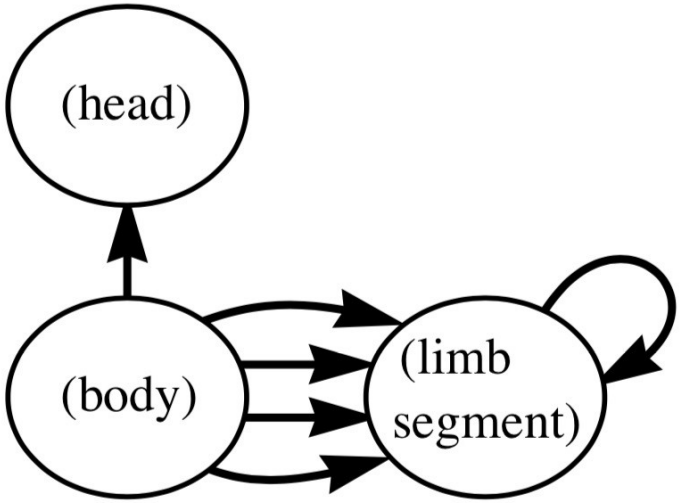




Evolving Virtual Creatures

- A **genome** is a set of nodes and links that encode a creature's body structure and brain structure

- Complex **genotype** → **phenotype** mapping



Evolving Virtual Creatures

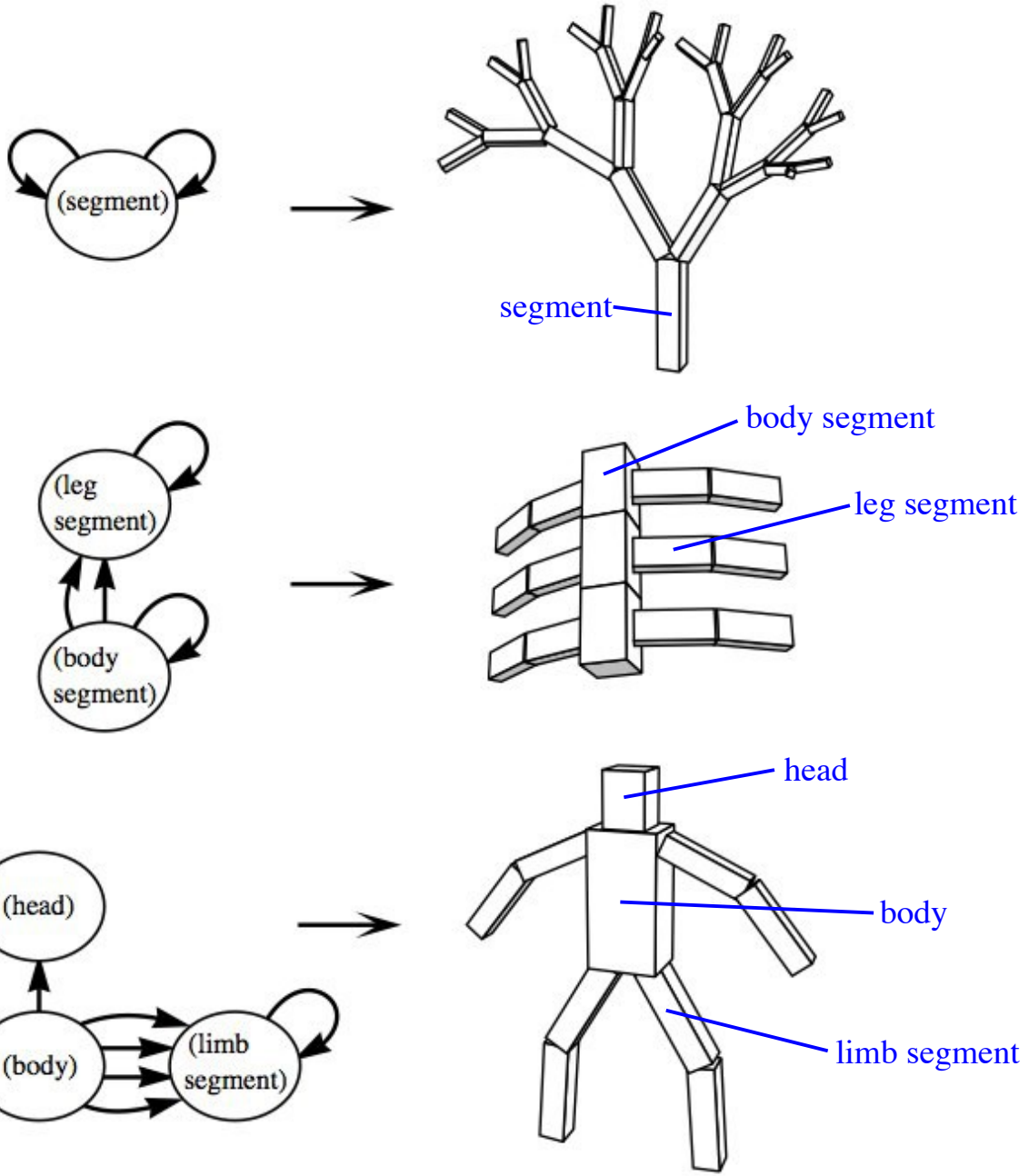
- A **genome** is a set of nodes and links that encode a creature's body structure and brain structure

- Complex **genotype** → **phenotype** mapping

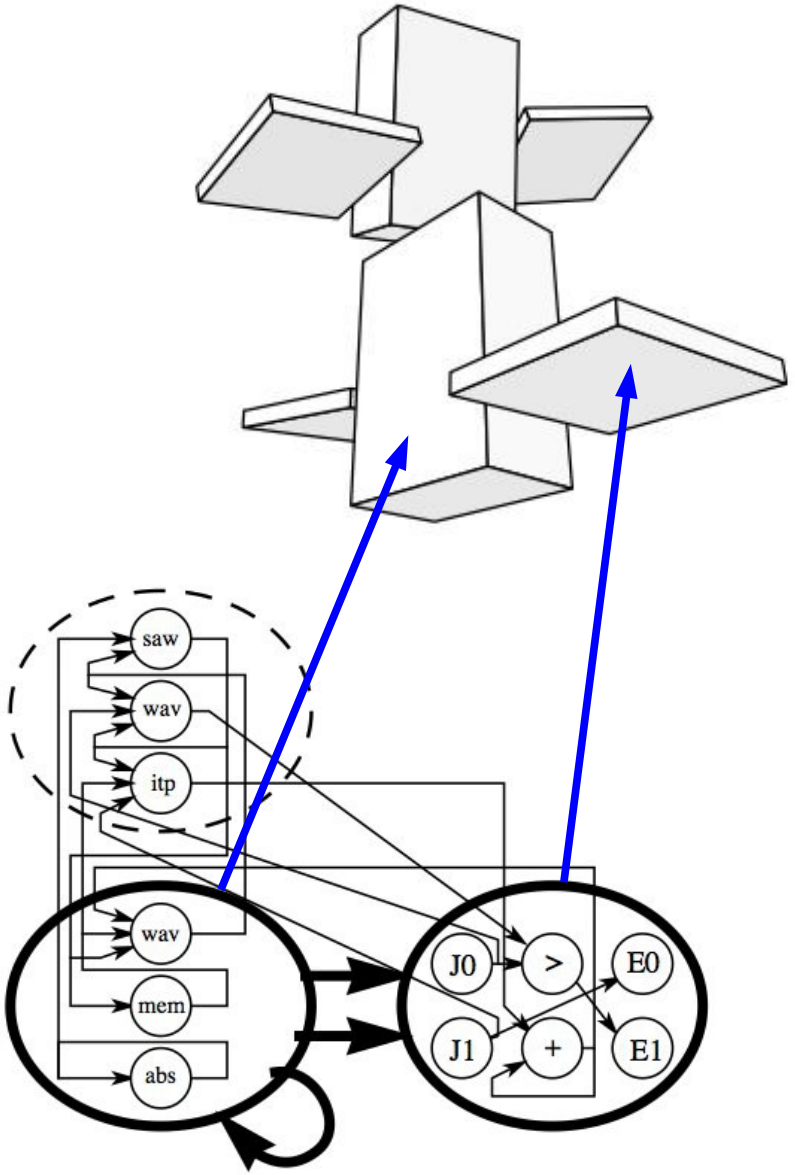
- Brains and bodies **co-evolve** together
  - Body structure evolves
  - Brain structure evolves (neural network topology)
  - Brain parameters evolve (neural network weights)

- Fitness: how well a creature can **swim**, **walk**, **jump**, **follow** a light source, or **compete** for control of a block

Genetic Encoding of Body Structure

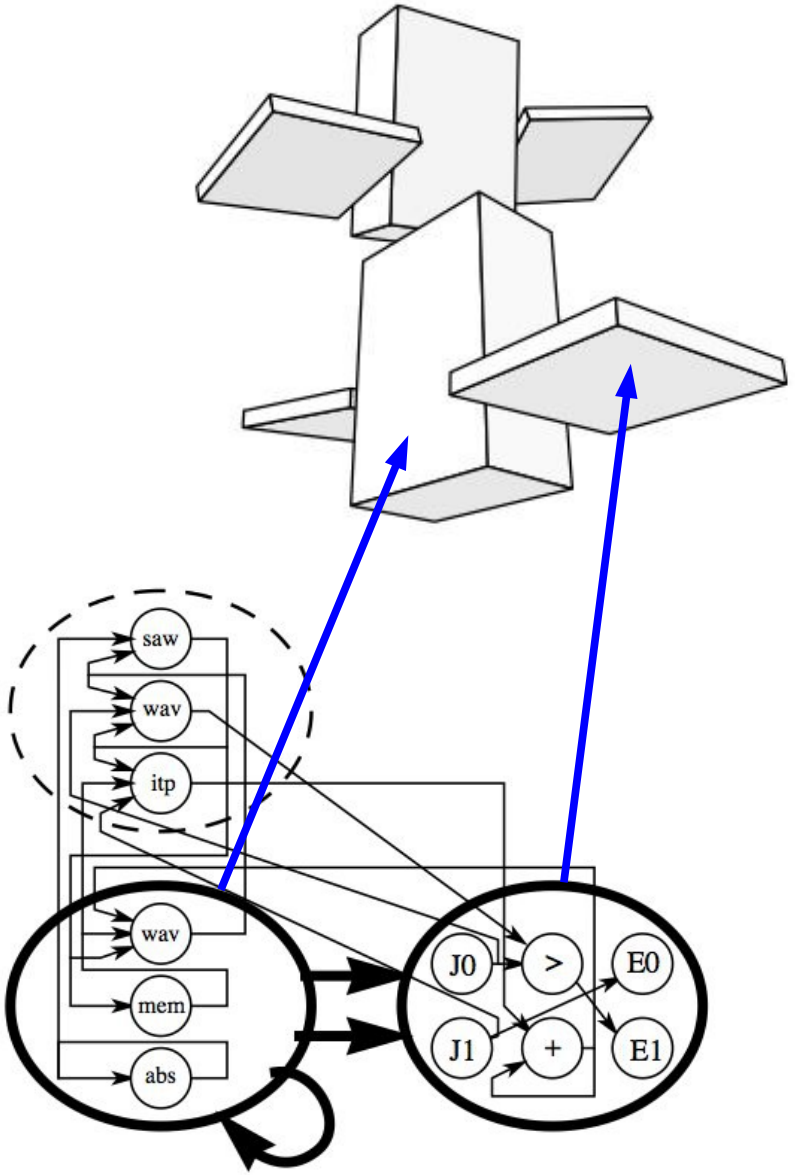


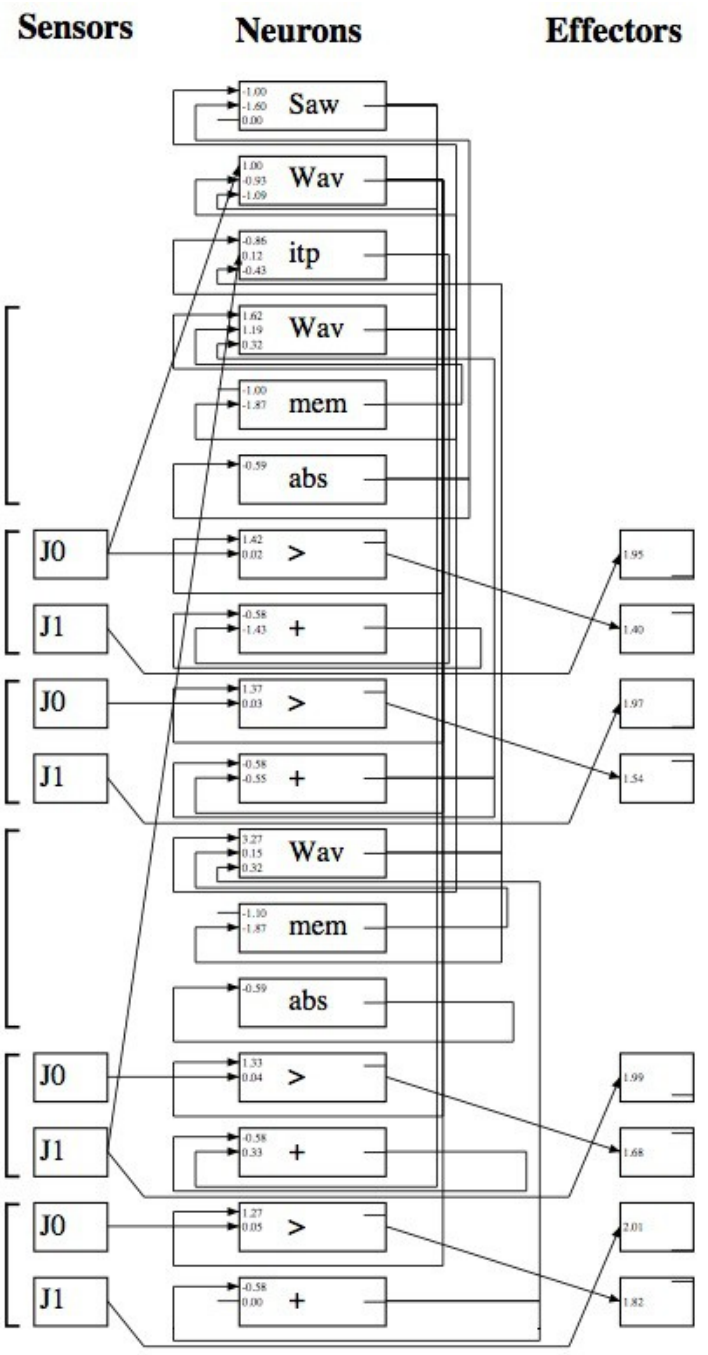
Genetic Encoding of Brain Structure



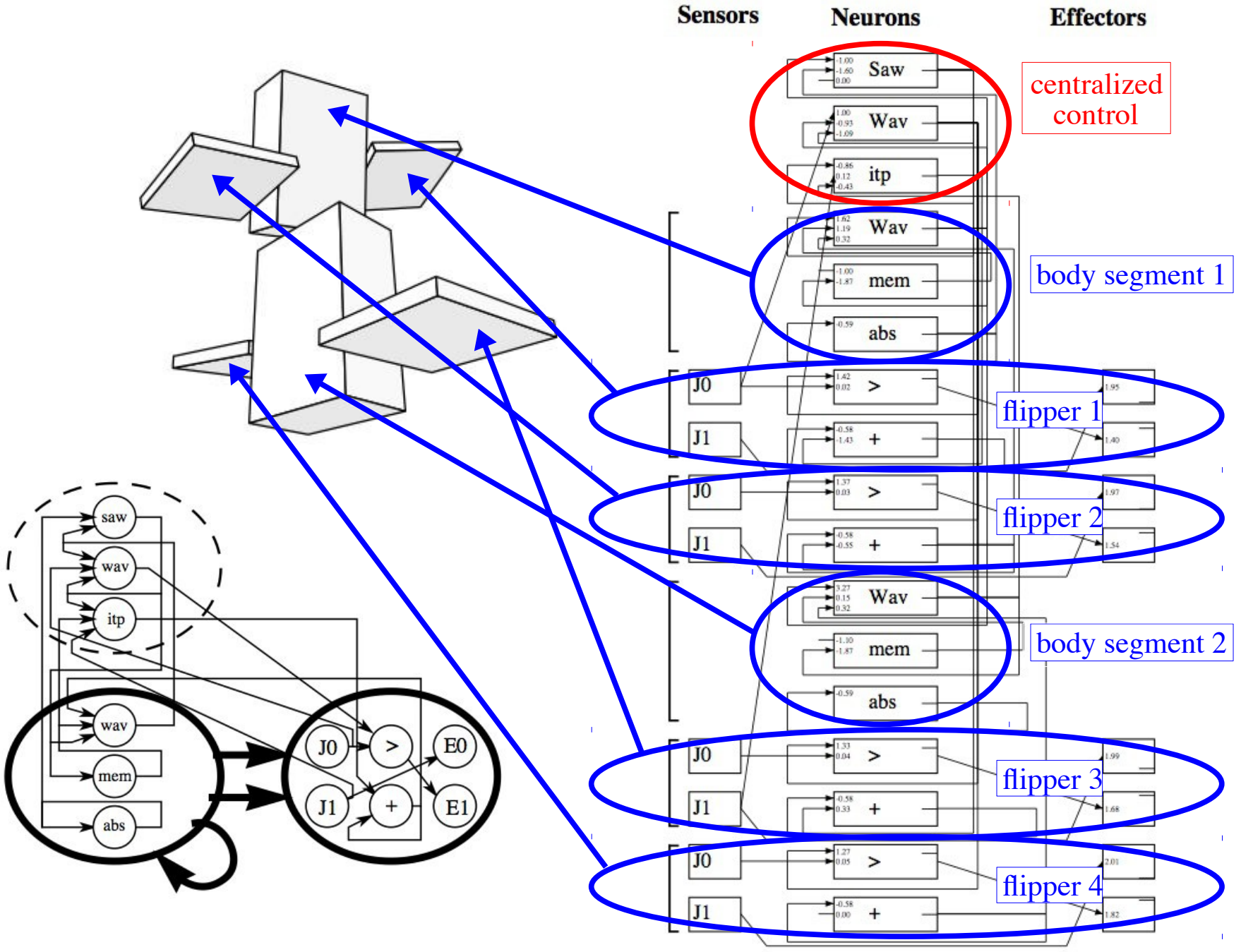
23 different neuron types:
sum, product, divide, sum-threshold, greater-than, less-than, sign-of, min, max, abs, if, interpolate, sin, cos, atan, log, expt, sigmoid, integrate, differentiate, smooth, memory, oscillate-wave, oscillate-saw

Genetic Encoding of Brain Structure

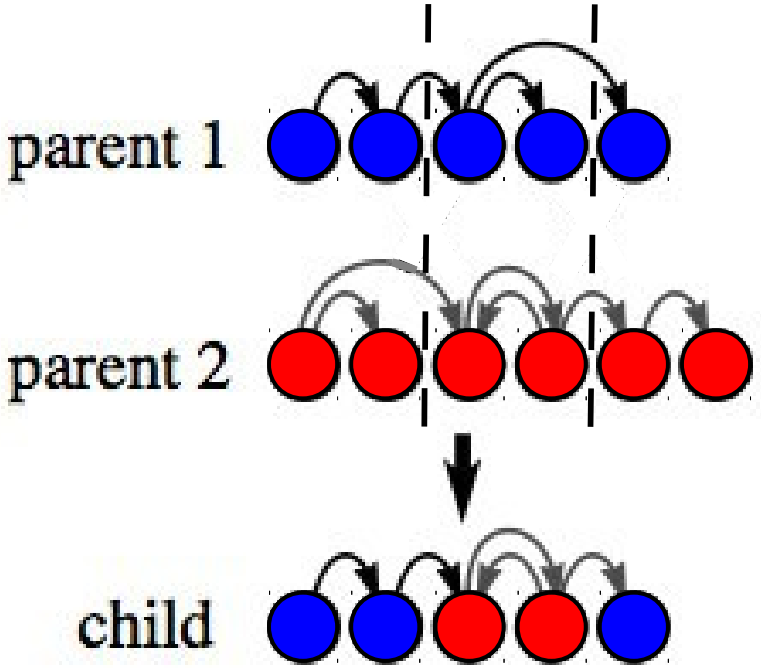




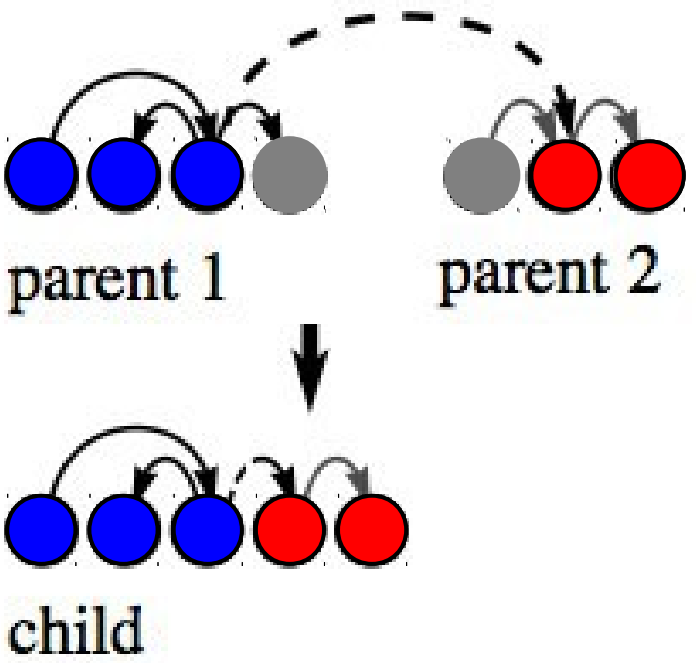
Genetic Encoding of Brain Structure



Genetic Recombination



Crossover



Grafting

The Genetic Algorithm

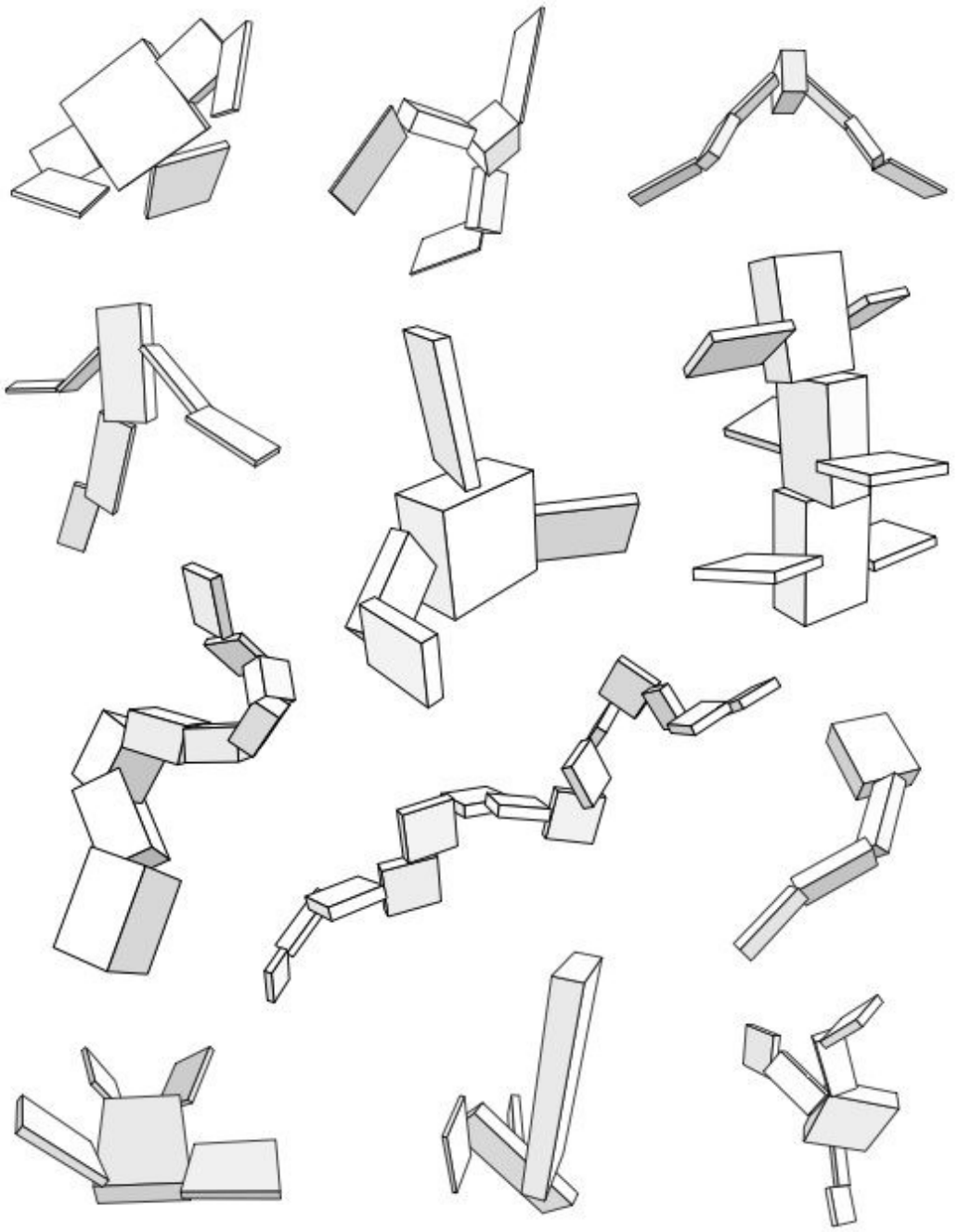
- Population size: 300 genomes
- Evolved for 100 generations
- Fitness evaluation:

genetic description → creature → 3-D simulation

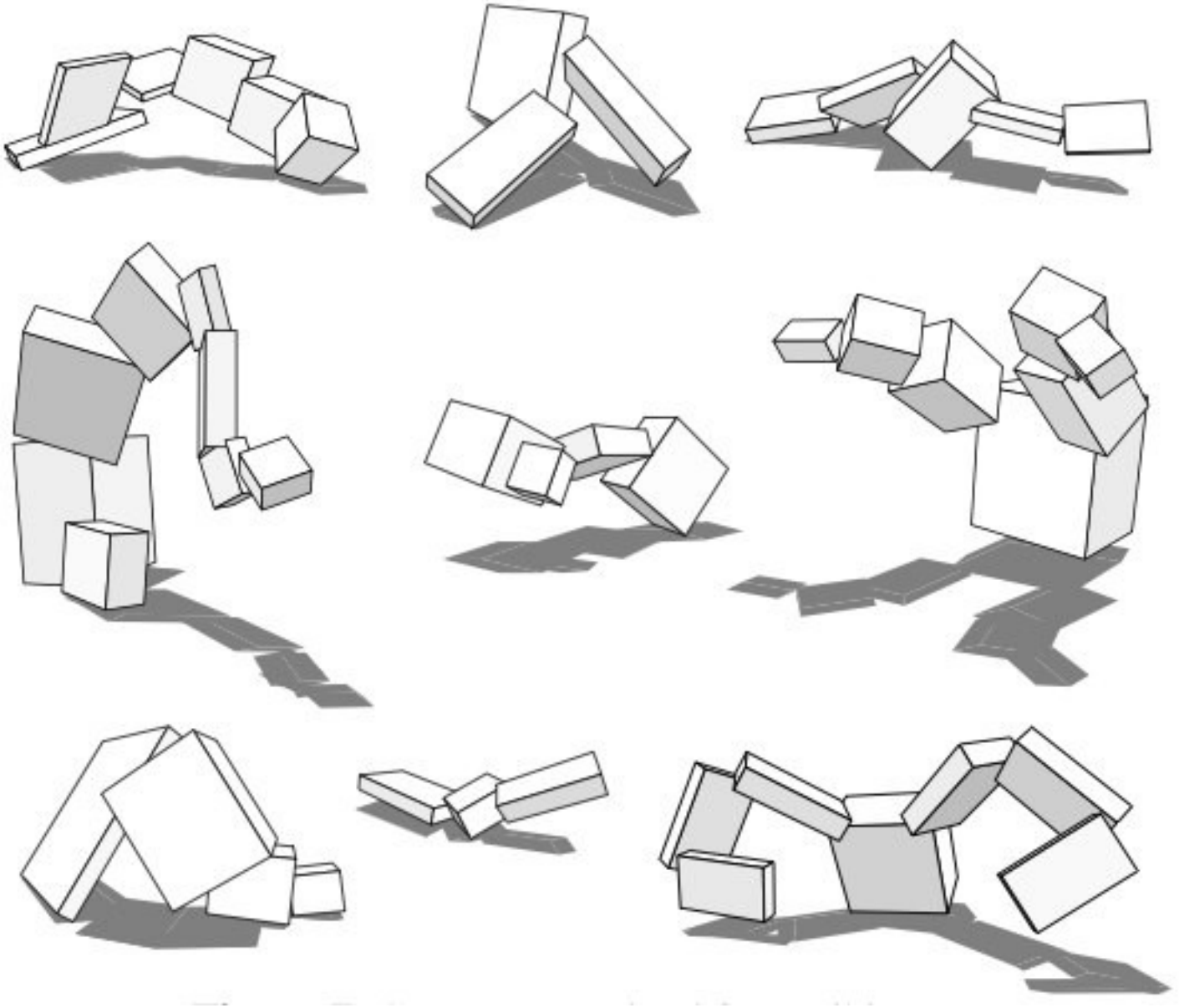
fitness = distance creature walks / swims / jumps / etc.
in a fixed amount of simulation time

- Virtual 3-D world simulates effects of gravity, friction, viscosity

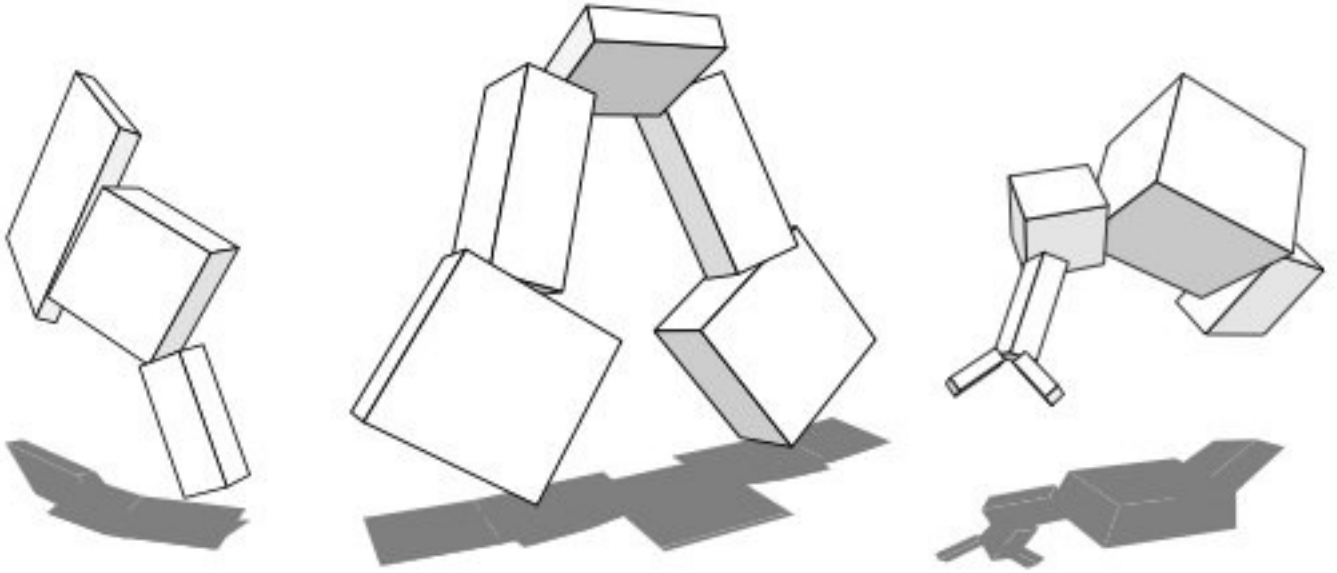
Results: Swimmers



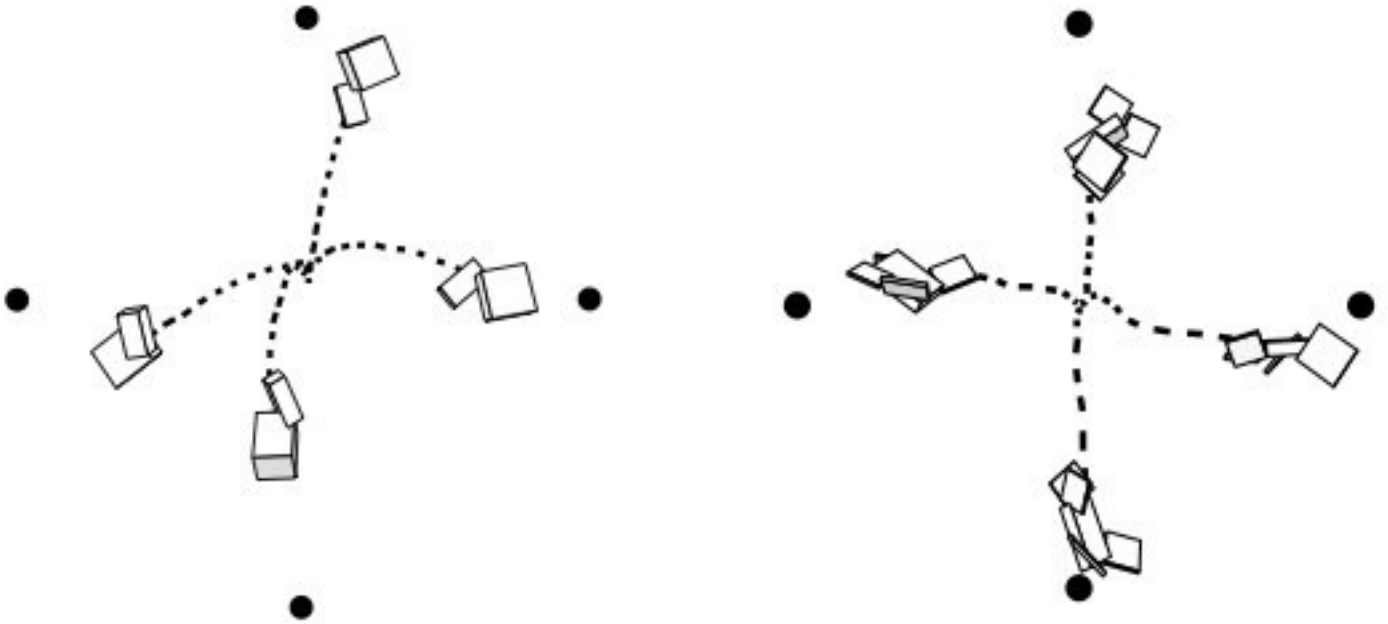
Results: Walkers



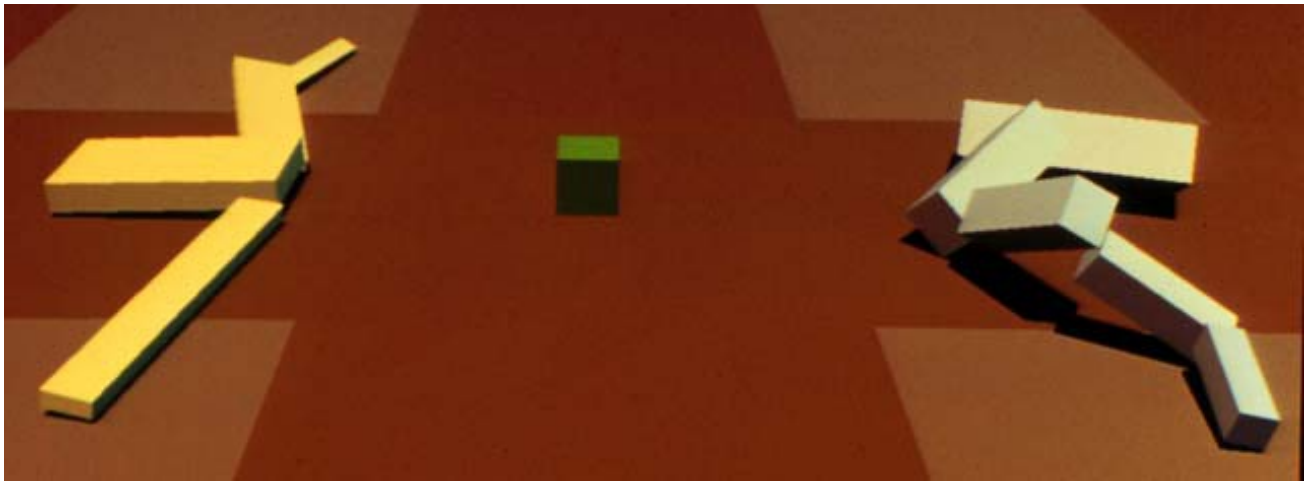
Results: Jumpers

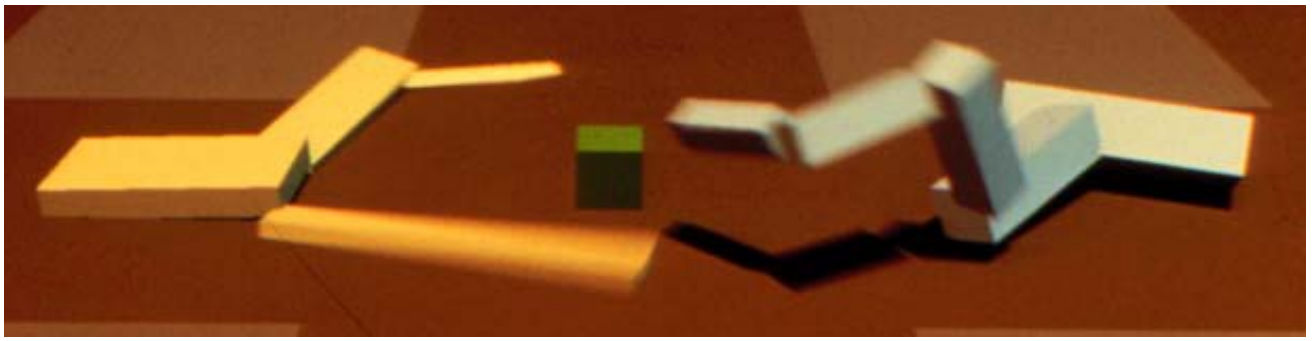


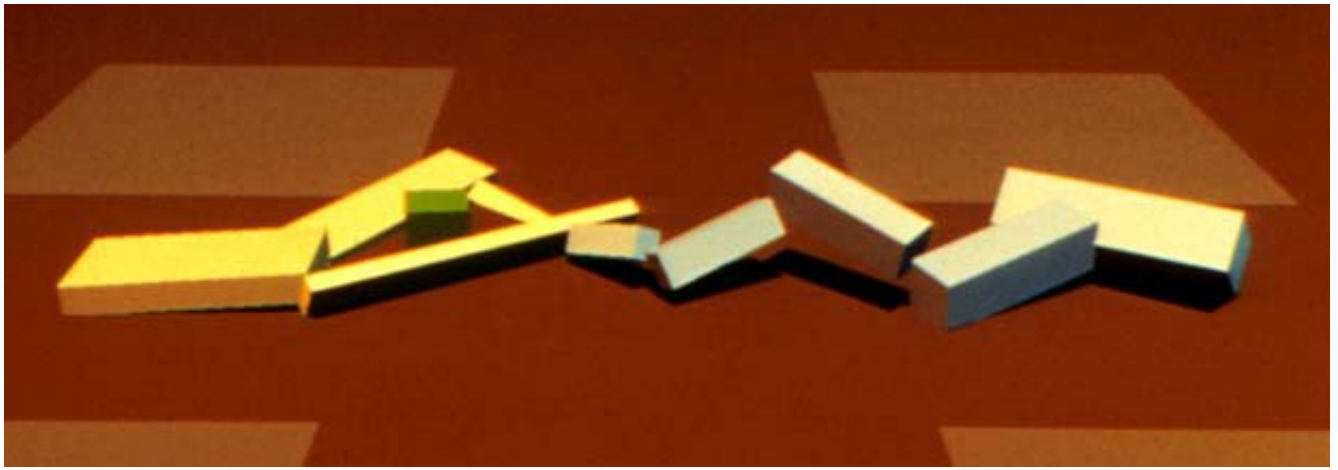
Results: Light Followers



Results: Competitors







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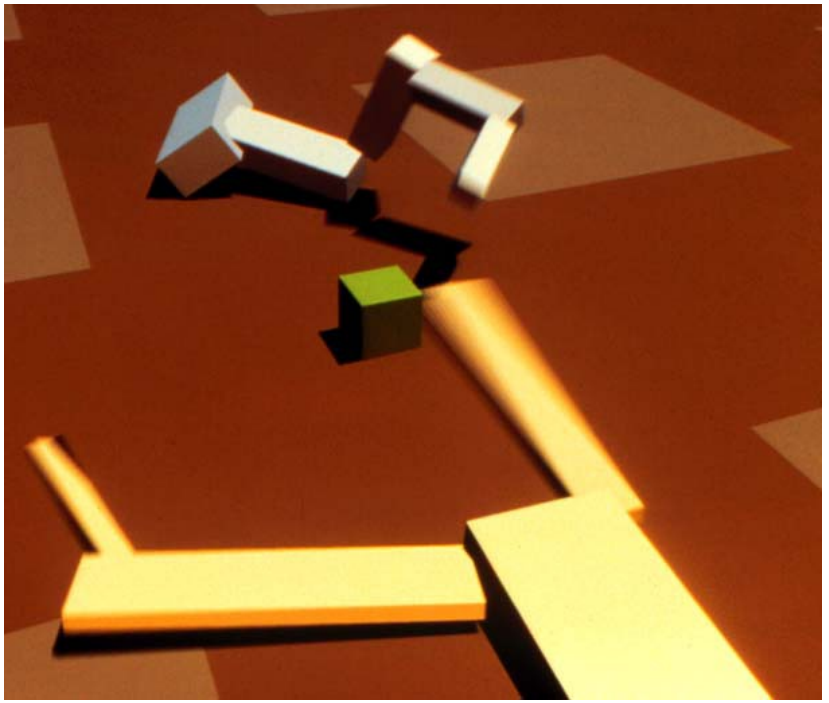

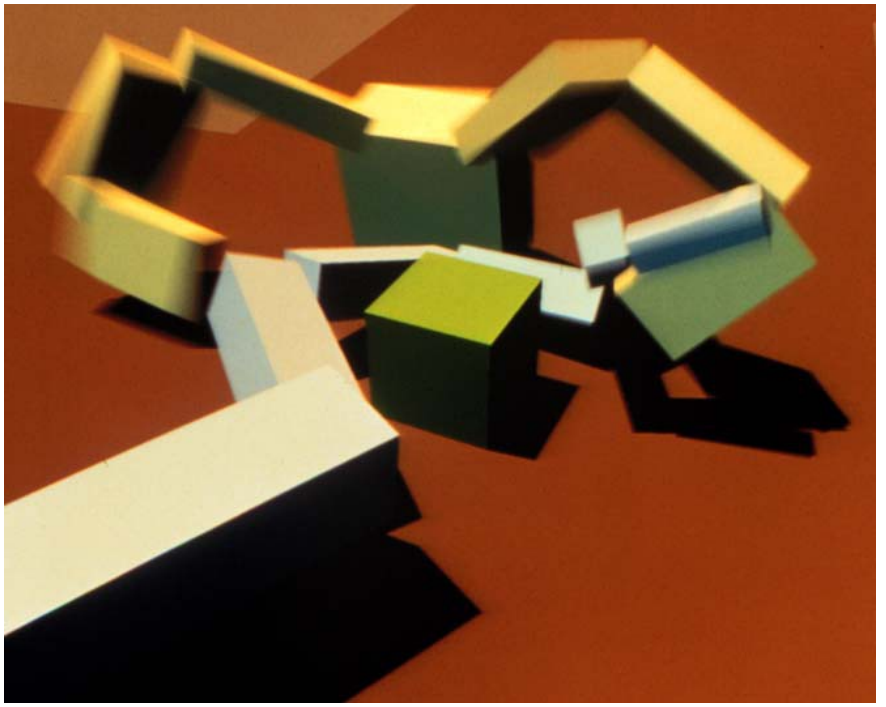

https://vimeo.com/235275454