CS 289
Evolutionary Robotics

From Artificial Life to Robots

- Chris Langton
  - 1987 coined the term artificial life
    - Many seminal (interdiscipline) papers
- **Karl Sims**
  - Evolved virtual creatures (SIGGRAPH and ALIFE 1994)
    - MacArthur Genius Award (1998)
    - MIT Media Lab, Thinking Machines, founded GenArts
- **Jordan Pollack's Lab**
  - **Evolving buildable structures (w Funes, 1998)**
  - **Evolving buildable robots (w Lipson, Science 2000)**
- Hod Lipson & Josh Bongard
  - New Ideas: Self-repairing robots (Science 2006)
  - Bongard: **Ludobots (evorobotics platform)**

- Many other EvoRobotics labs! (review article)

Karl Sims, ~1994

Evolved ALIFE
- Representation
- Variation
- Evaluation
- **Results**

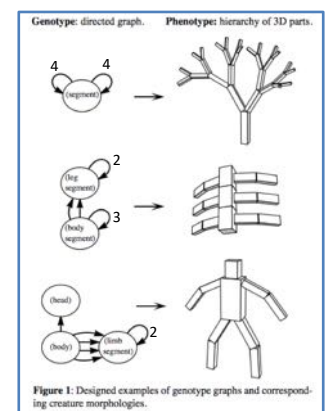*Walking, Swimming, Hopping, Following, Competing*

Representation

Morphology: Directed graph representation

Variation:
1. Add body elements. Add different kinds of joints.

2. "Generative" language! (can add loops to create copies of structures)

3. Cross-over!

Genotype: directed graph.   Phenotype: hierarchy of 3D parts.

Figure 1: Designed examples of genotype graphs and corresponding creature morphologies.

Slide 1:

Representation

Control:
Sensors->Neurons->Motors
Sensors = joints angles, contact
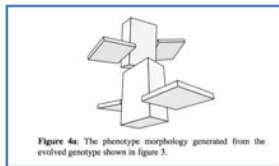Neurons = lots of types!

Variation: Mutation and Cross-Over

Figure 4a: The phenotype morphology generated from the evolved genotype shown in figure 3.

Sensors (joint angles) — Neurons — Effectors (motor values)
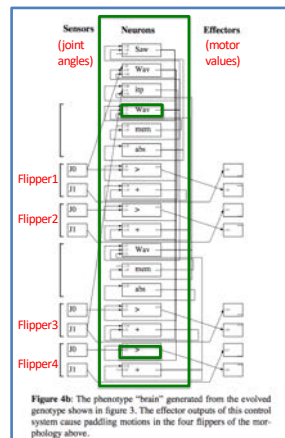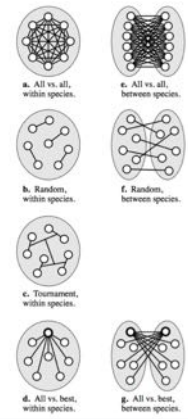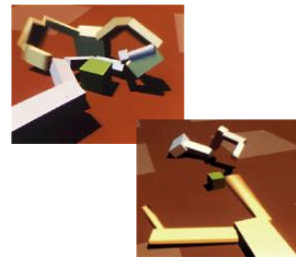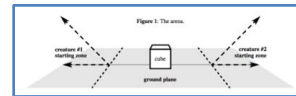
Flipper1, Flipper2, Flipper3, Flipper4

Figure 4b: The phenotype "brain" generated from the evolved genotype shown in figure 3. The effector outputs of this control system cause paddling motions in the four flippers of the morphology above.

Slide 2:

Competition! (Co-evolution)

Figure 1: The arena.
creature #1 starting zone — cube — creature #2 starting zone — ground plane

a. All vs. all, within species.
b. Random, within species.
c. Tournament, within species.
d. All vs. best, within species.
e. All vs. all, between species.
f. Random, between species.
g. All vs. best, between species.

Slide 3:

Karl Sims, ~1994

Evolved ALIFE
- Representation
- Variation
- Evaluation
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Walking, Swimming, Hopping, Following, Competing

Slide 4:

"The question that was begging to be asked was can something similar be done in the physical world?

Can we make creatures that walk out of the computer screen and into the world?"

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Lipson and Pollack, Science 2000

The Golem Project
- Representation
- Variation
- Evaluation
- Results
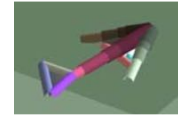
Lipson and Pollack, Science 2000

Representation   Variation   Evaluation   Results

Bongard, Zykov & Lipson, Science 2006
aka What do Robots Dream of?

- Resilient Machines Through Continuous Self-Modeling
  - Learn/evolve a model of your own self
  - Compare your actions to your expectations
  - Iterate

- Key Ideas
  - Don't need to simulate the full task to learn a model of yourself.