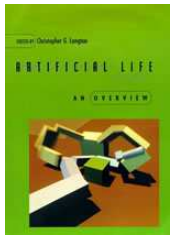
seminar in artificial life
csc 84200

today's topics:

- introduction to arficial life
- karl sims: evolving virtual creatures
- hod lipson: automatic design and manufacture of robotic lifeforms

what is artificial life?

- Artificial Life: An Overview (Complex Adaptive Systems) by Christopher G. Langton (Editor) Publisher: The MIT Press (1995)



- four levels [Taylor and Jefferson, 1995 (ch1 of above book)]:
  1. molecular level — "wetware" (biology labs)
  2. cellular level — "software" (cellular automata)
  3. organism level — "hardware" (robotics)
  4. population level — "multiagent systems" (swarms, social networks)

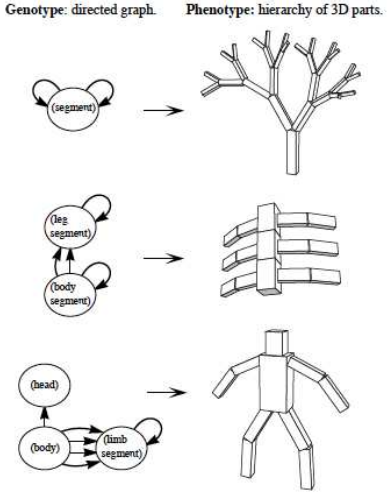
karl sims

- Evolving Virtual Creatures, by Karl Sims (1994), Proceedings of SIGGRAPH'94.

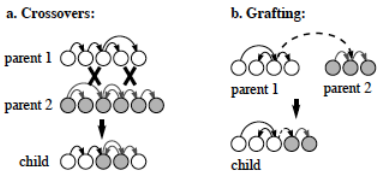
- classic trade-off: complexity vs control, e.g., dynamic simulation vs kinematic control
- evolve "body" and "brain" together: *hyperspace* of possibilities to explore

- evolutionary computation: *population-based approach* to machine learning
  1. initialize population
  2. perform some task
  3. measure fitness
  4. select "fittest"
  5. reproduce
  6. loop back to step 2 for next generation
- when are you done?
- how do you keep exploring new regions in the "hyperspace"?
  exploration versus exploitation
- what is the best representation?
  - genetic algorithm (bit string)
  - genetic program (s-expression)
  - neural network

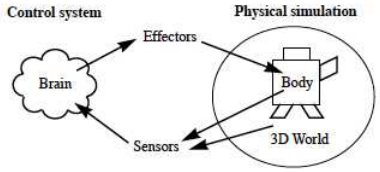
- genetic algorithms: *genotype* = coded representation, *phenotype* = physical representation



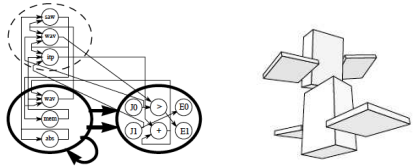
- *reproduction*
  - mutation
  - crossover
  - grafting



- *selection*
  - performance
  - fitness metric



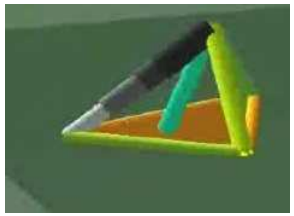
- morphology ("body")
  - dimensions
  - joint type (e.g., rigid, revolute, twist, ...)
  - recursive-limit
  - neurons ("brain")
  - connections (to other nodes)
- control ("brain")
  - sensors (joint, contact, photo)
  - neurons (functions, e.g., sum, product, divide, ...): map sensor input to effector output
  - effectors (amount of force on a joint)
- morphology and control are combined



- physical simulation (body dynamics, collision detection, collision response, friction, ...)
- evolution
  - selection for specific behaviors: swimming, walking, jumping, following
  - reproduction using: random mutation (40%), crossover (30%), grafting (30%)
- results — see the movie!!

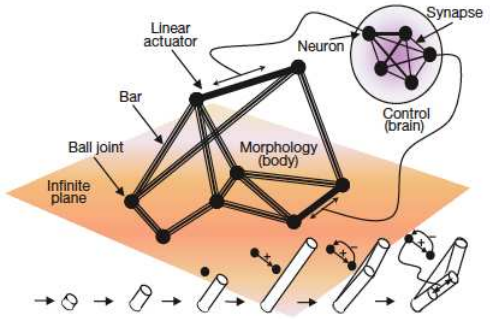
hod lipson

- Automatic design and manufacture of robotic lifeforms, by Hod Lipson and Jordan Pollack (2000), Nature, volume 406.

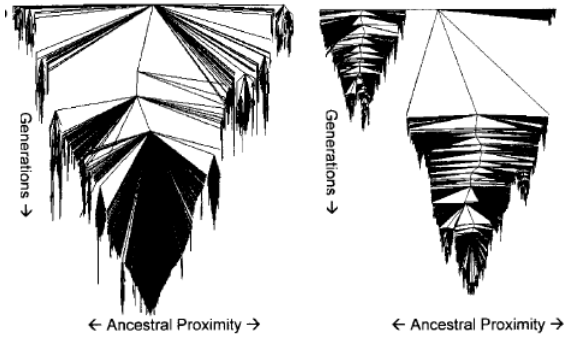


- response to Sims' work
- uses REAL physics and REAL creatures

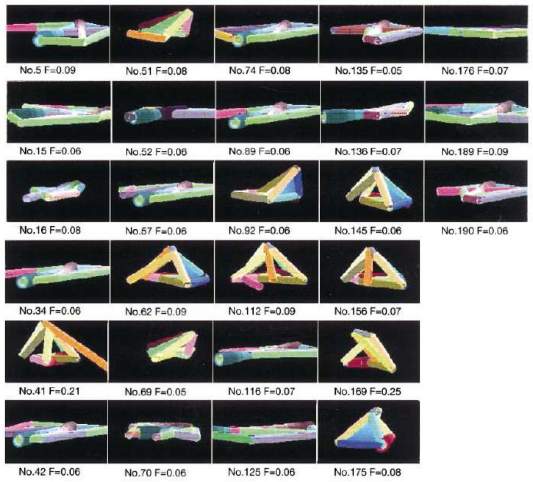
- neural network representation of *body* and *brain*



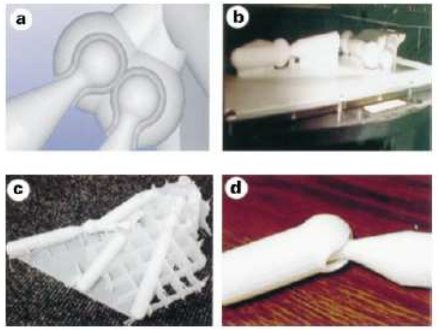
- evolve many generations in simulation
- phylogenic trees:



- one generation:



- physical construction, using a 3D printer:



- and the results? see the movie!