Human
Computer
Interaction

Artificial Evolution

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July, 2009

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Outline

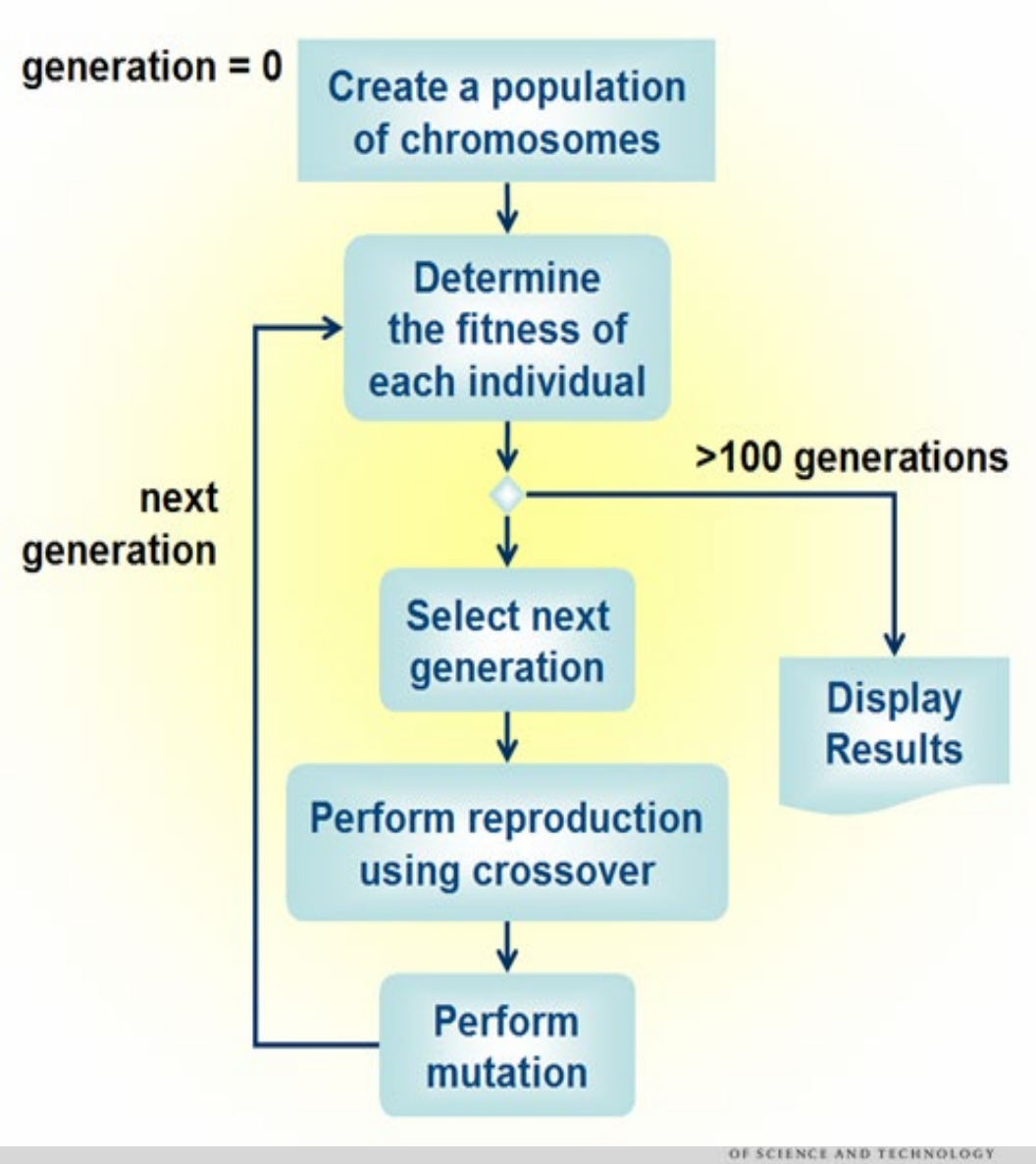
- Genetic Algorithms
  - What are they?
  - Demo: finding the minimum of $y=x^2$
  - Demo: designing catapults
  - Applications
- Evolving Neural Controllers
  - What's a neural network?
  - Video: evolving bipedal behaviors
  - Video: evolving bodies + brains
- Further Reading…

What's a Genetic Algorithm?

- Random search + selection pressure = optimization towards a desired goal
- Represent something to optimize as a string of genes
  - Phenotype: the physical "body"
  - Genotype: the "DNA," a compact, numeric representation of phenotype
- Define fitness function to compare phenotypes… what is the desired result?

How to Use It...

- create random initial population
- for each generation:
  - generate bodies from genes
  - evaluate each body on the fitness function
  - keep the "best" genes in the population, delete the worst
  - generate new offspring from those kept to replace those deleted:
    - crossover/sexual reproduction (optional): combine chunks of genes from two randomly chosen parent genomes
    - mutation: randomly perturb a few genes



Source: http://www.edc.ncl.ac.uk/highlight/rhjanuary2007g01.php

Demo
Find the minimum of $y=x^2$

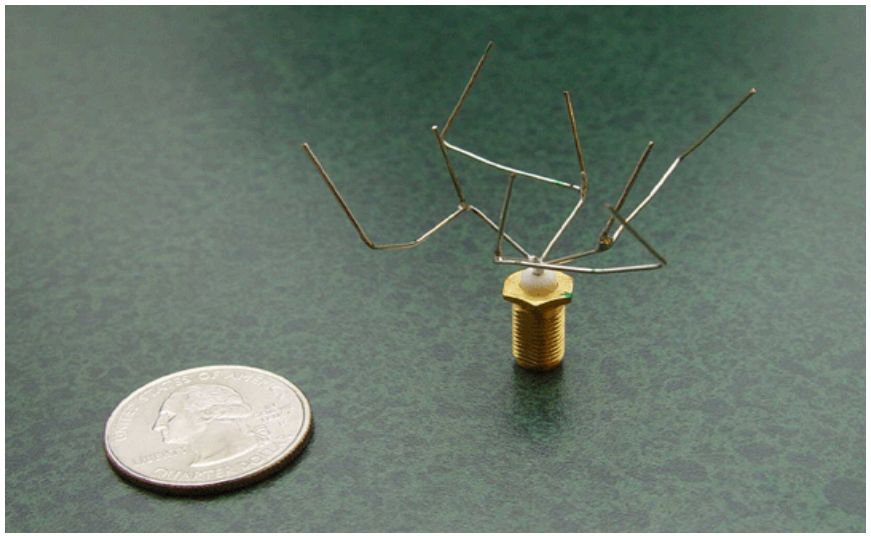
- Genotype: just 1 gene representing position along x axis
- Fitness function: 1/y (smaller y is favored)

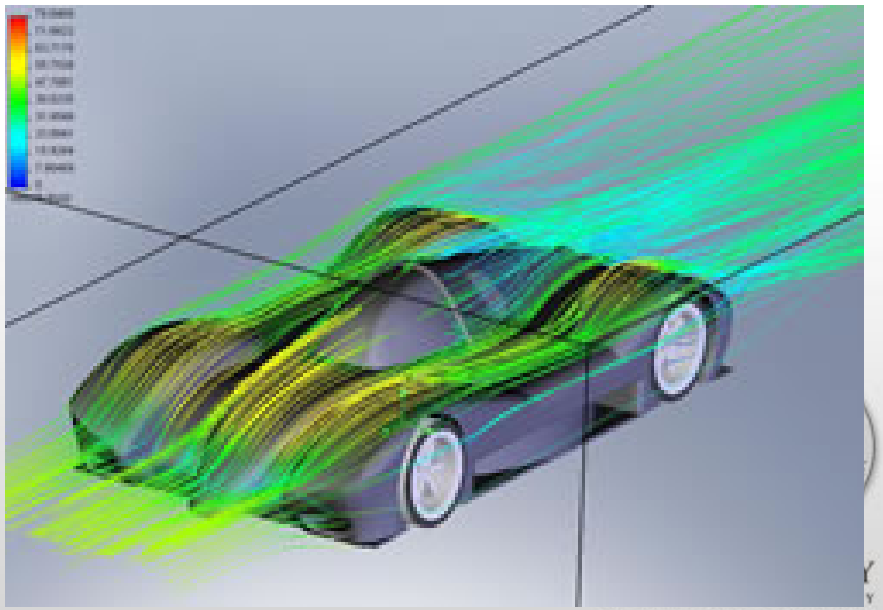
Demo
Designing Catapults

- Genotype: 3 genes
  - 1 gene represents length of lever
  - 1 gene represents fulcrum position
  - 1 gene represents mass of counterweight
- Fitness function: distance of launched projectile's impact with the ground

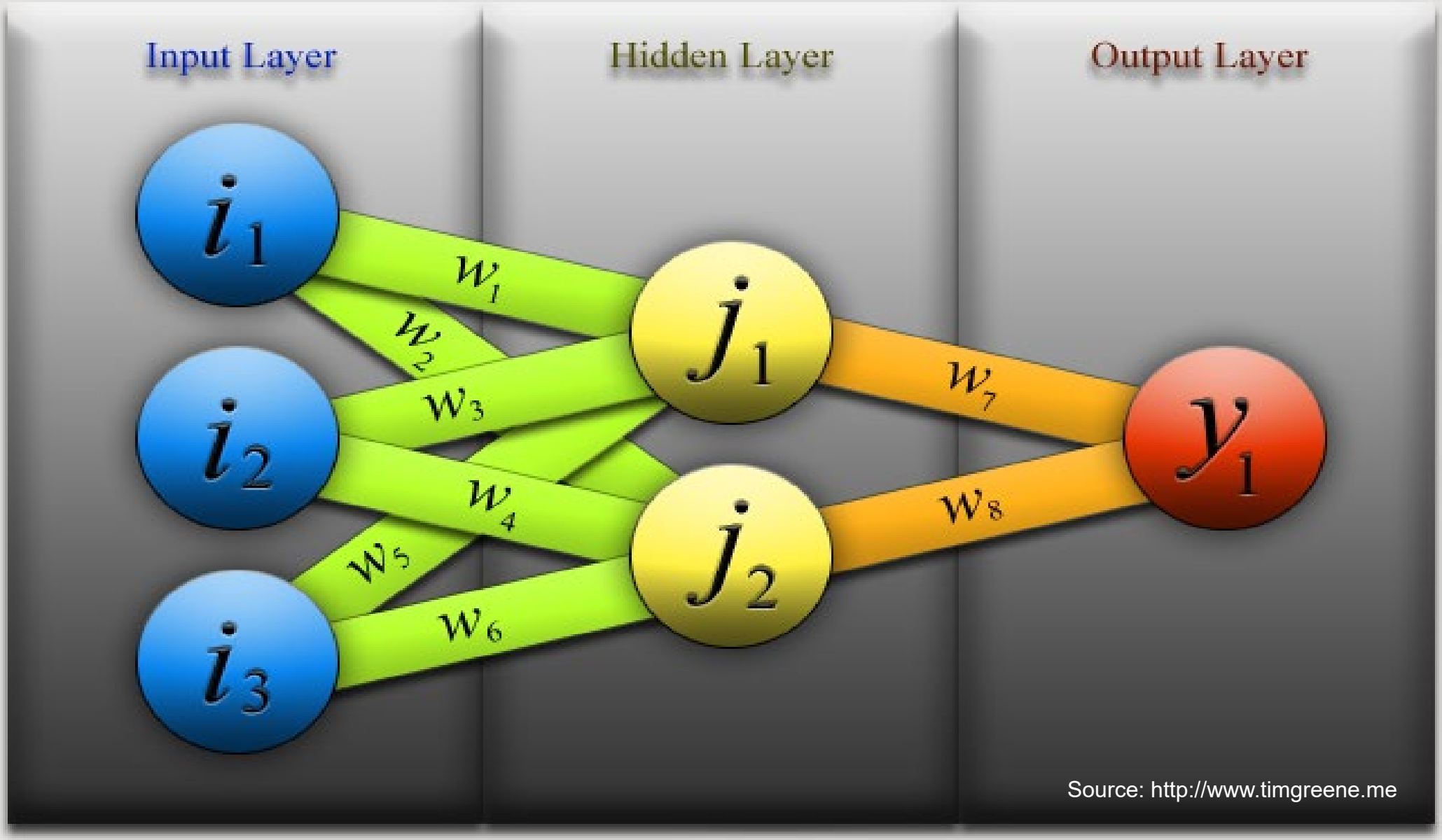
Other Applications

- Evolving antenna designs
- Evolving aerodynamic shapes (airplane wings, cars, etc.)
- Evolving optimal computer keyboard layouts
- Evolving circuit design (FPGAs)
- Evolving GCC compiler options
- Evolving protein folding configurations
- Evolving robot brains…



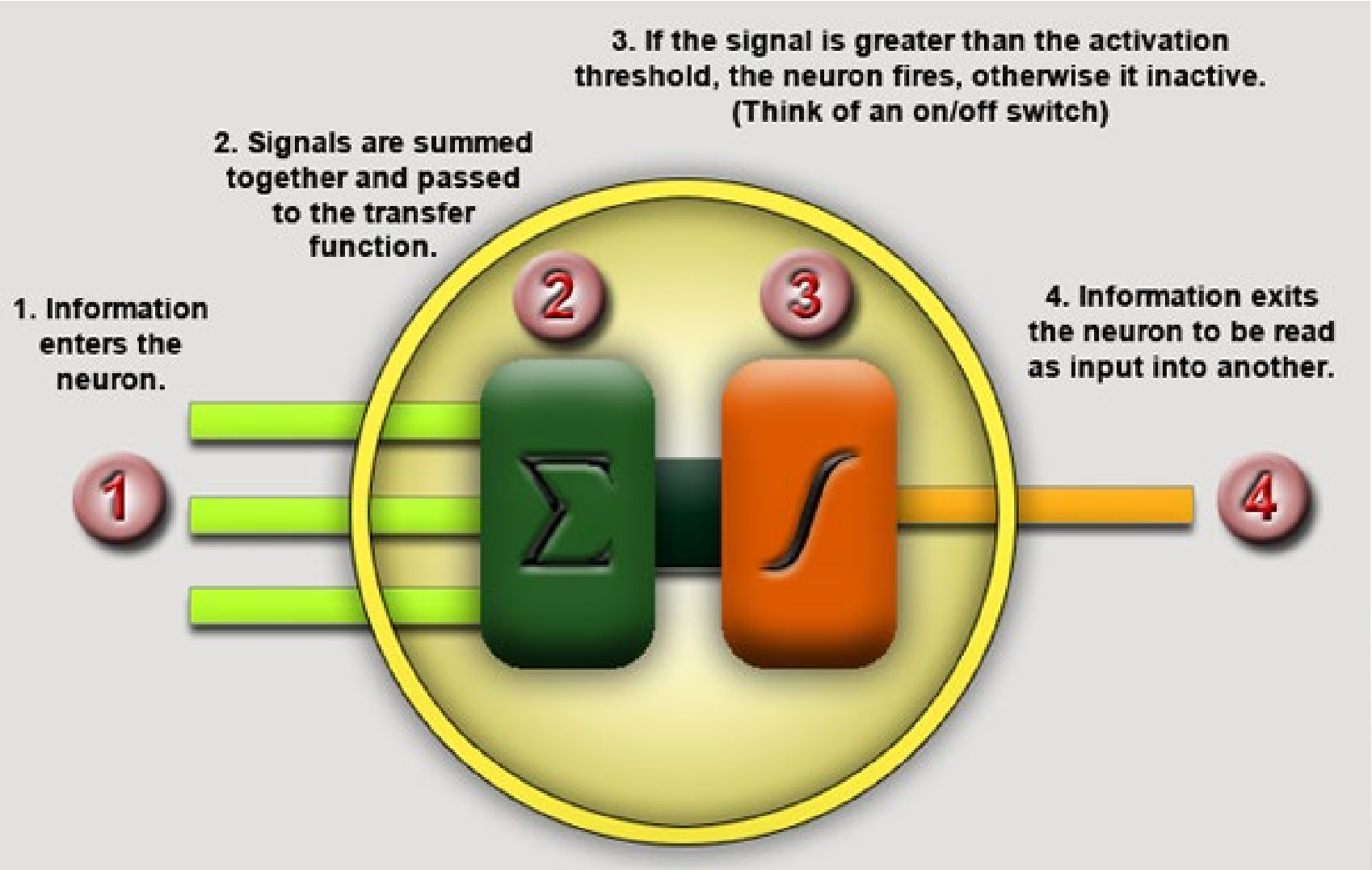


What's a Neural Network?



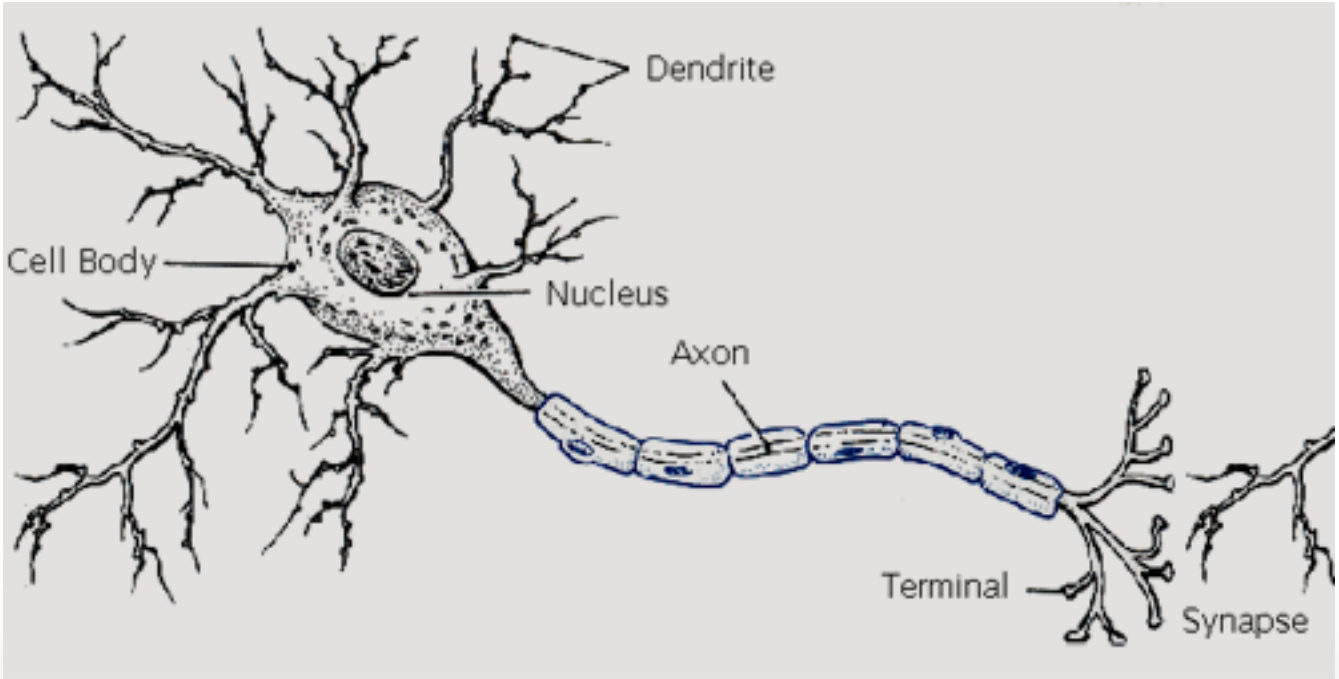
Source: http://www.timgreene.me

Abstract Neural Activation



Source: http://www.timgreene.me

Biological Neurons



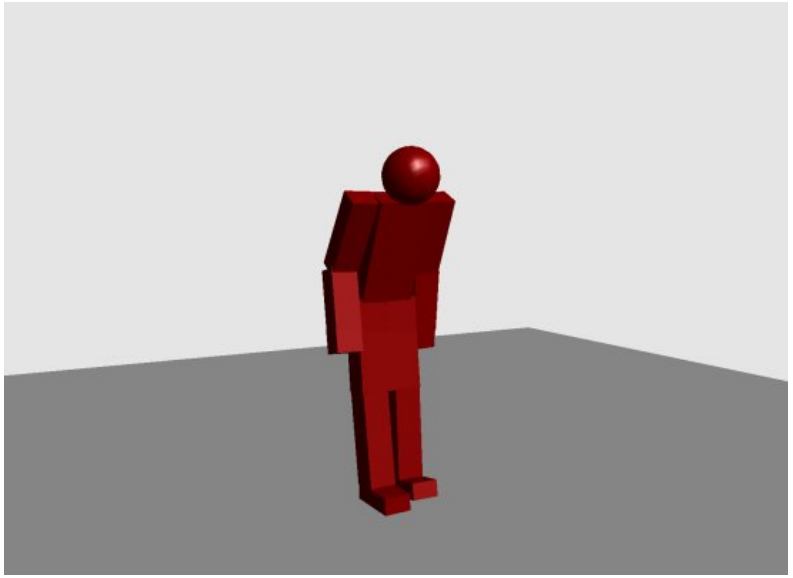
Source: http://www.timgreene.me

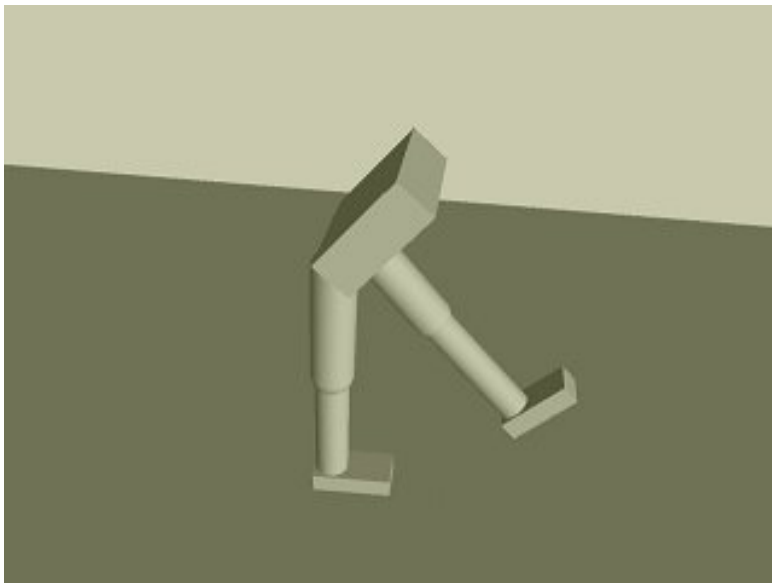
How Can We Use a Neural Network?

- Can represent arbitrary function mapping input vector to output vector
- Connection weights/strengths determine function
- Weights can be adapted, e.g., by a genetic algorithm
  - Artificial evolution of neural controllers, e.g., for robots
  - Learning of complex multi-dimensional control with little human feedback

Research Goal: To Make Simulated Humans Come to Life

Evolution of Standing, Jumping, & Walking

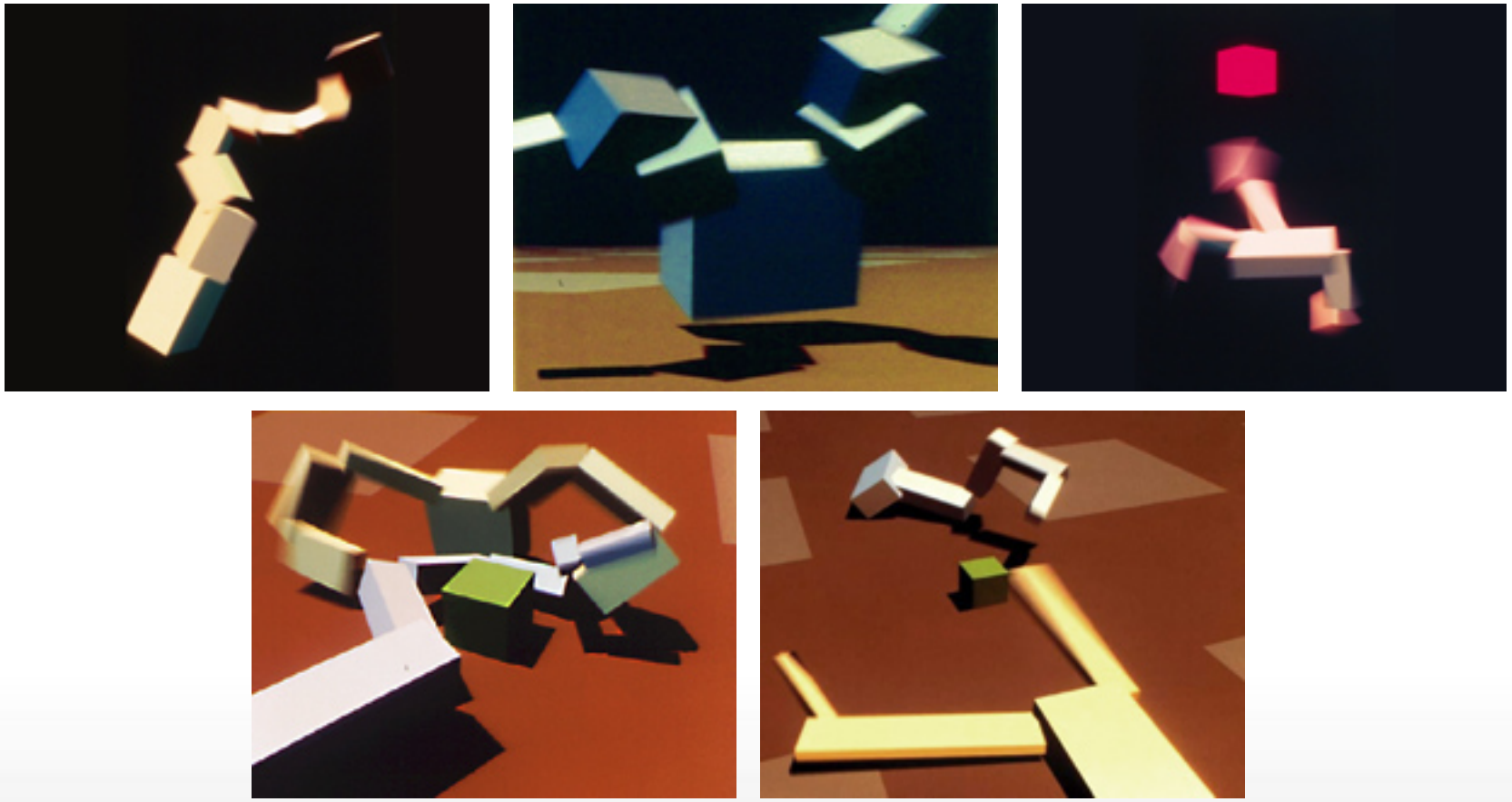




Tyler Streeter, 2003

- Standing: http://video.google.com/videoplay?docid=-2510462304066175045
- Jumping: http://video.google.com/videoplay?docid=10020620309825518 47
- Walking: http://video.google.com/videoplay?docid=-115050862004797295 1

Evolving Bodies *and* Brains



Karl Sims, Evolved Virtual Creatures, 1994

Swimming, hopping, following, & competing behaviors

http://www.youtube.com/watch?v=gFWDxqcZqvY

Further Reading

- Genetic algorithms
  - http://www.edc.ncl.ac.uk/highlight/rhjanuary2007g01.php
  - http://en.wikipedia.org/wiki/Genetic_algorithm
- Evolving neural controllers
  - http://www.evolutionaryrobotics.org
  - Evolutionary Robotics by Nolfi and Floreano
  - Karl Sims papers
    - http://www.genarts.com/karl/papers/siggraph94.pdf
    - http://www.genarts.com/karl/papers/alife94.pdf