

# Genetic Algorithms, Artificial Life and Computer Games



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# Outline of lecture

- Introduction to genetic algorithms
- Evolving creatures in virtual worlds
  - Movement controller only
  - Movement controller and body shape
  - Other examples of evolved game content
- Introduction to artificial life
- Artificial Life in games
  - Biochemistry, communication and learning
  - Ecosystems
- Future directions

# Genetic Algorithms

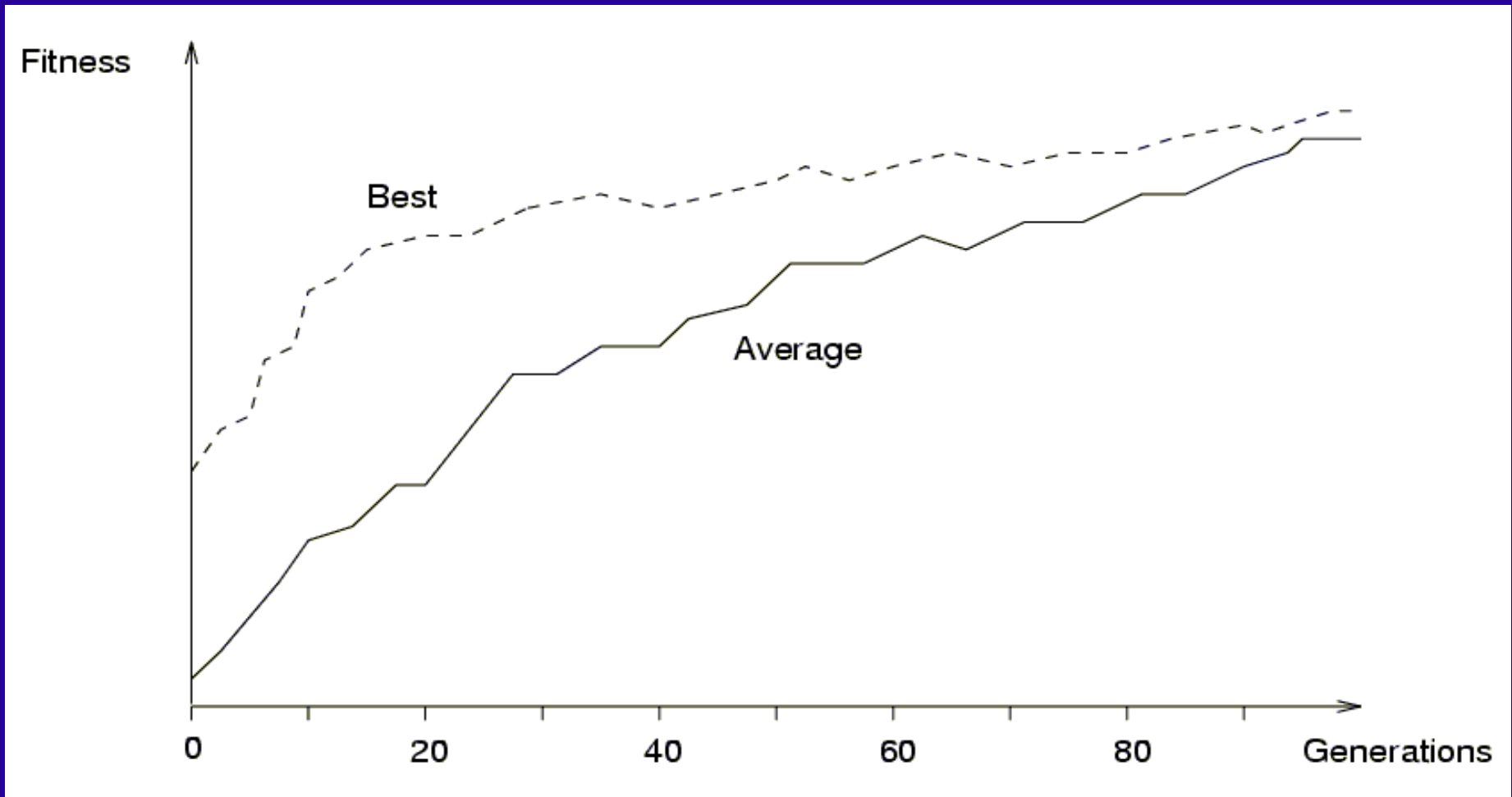
- An **optimisation** technique modelled on the process of **Darwinian evolution**
- Introduced by John Holland in the 1970s
- Can be used on problems where you have very little idea of how to solve them
- Involves a **population** of individuals
- Each individual is an **encoded** solution to the problem
- A **fitness function** is defined, to give each individual a numeric score according to how well it solves the problem

# Genetic Algorithm Pseudocode

The general idea is very simple, but surprising powerful in many situations

- Generate a set of random solutions
- Repeat
  - Test each solution in the set and rank them
  - Remove some bad solutions from set
  - Duplicate some good solutions
  - Make small changes to some of them
- Until "best" solution is good enough

# GA: example of convergence



Graph from <http://www.ee.pdx.edu/~mperkows/temp/0101.Genetic-Algorithm.ppt>

# GA example: evolution of walking

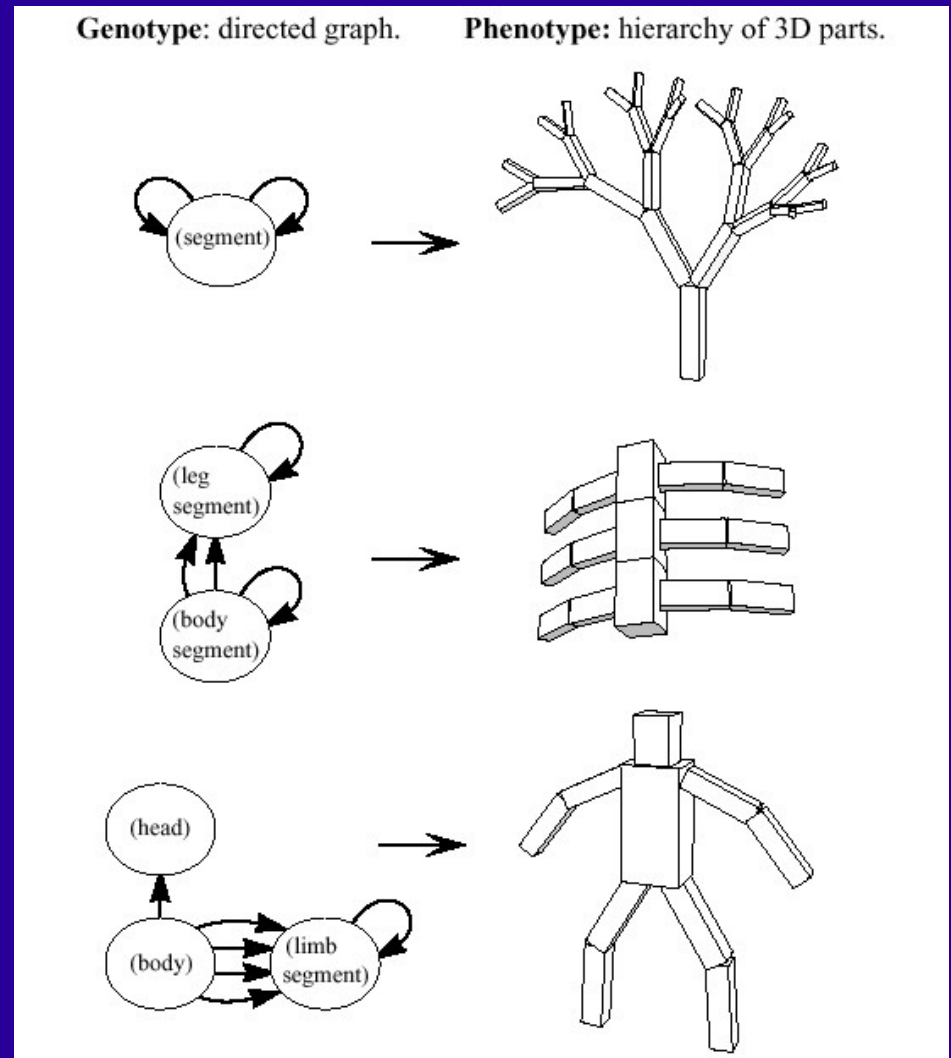
- Example application by NaturalMotion Ltd, 2002:
- Model a creature (e.g. human) in a 3D virtual environment with simulated physics
- Use a genetic algorithm to evolve a controller for the creature's limb movement
- [MOVIE]

# Evolving Creatures in Virtual Worlds

- Have just seen an example of evolving a controller for a **pre-defined body shape**
- How about evolving not just the movement, but the **body shape as well?**
- **Karl Sims** published some seminal work on this in 1994, using a parallel computer (Connection Machine)
- By 1999, it was possible to do the same thing on a desktop PC
  - e.g. work by Taylor & Massey at MathEngine PLC

# Evolving body shape and controller

- Sims used embedded graphs to represent body shape and controller
- Used different environments and/or fitness functions to evolve various behaviours, e.g.
  - Swimming
  - Walking
  - Jumping
  - Following
  - Co-evolution of contestants in cube-possession game



# Karl Sims explains his work

- [MOVIE]
- Some things to note:
  - Lifelike movement is a result of the **interaction** of a creature's movement within a realistically modelled physical environment
  - Evolution is a good way to **explore large search spaces** and find **creative solutions**

# Examples of evolved creatures

- [SIMS MOVIE]
- [TAYLOR & MASSEY MOVIE]
- MathEngine  $\Rightarrow$  NaturalMotion  $\Rightarrow$  Hollywood

# Other examples of evolved content

- **Kenneth Stanley's** group at University of Central Florida
- **NERO** (Neuro Evolving Robotic Operatives)
  - Users evolve controllers for NPC robotic soldiers
  - Game has two phases: training then battle (quite a niche game)
  - Over 100,000 downloads
- **Galactic Arms Race (GAR)**
  - An online multi-player space combat game
  - Weapons modelled as particle systems
  - New weapons evolve as the game is played, based upon which ones a player uses most
  - Evolution happens in the background

# GAR: Evolved Weapons



Ladder gun



Spread gun



Ultra wide



Tunnel maker



Corkscrew



Wall maker

# Artificial Life

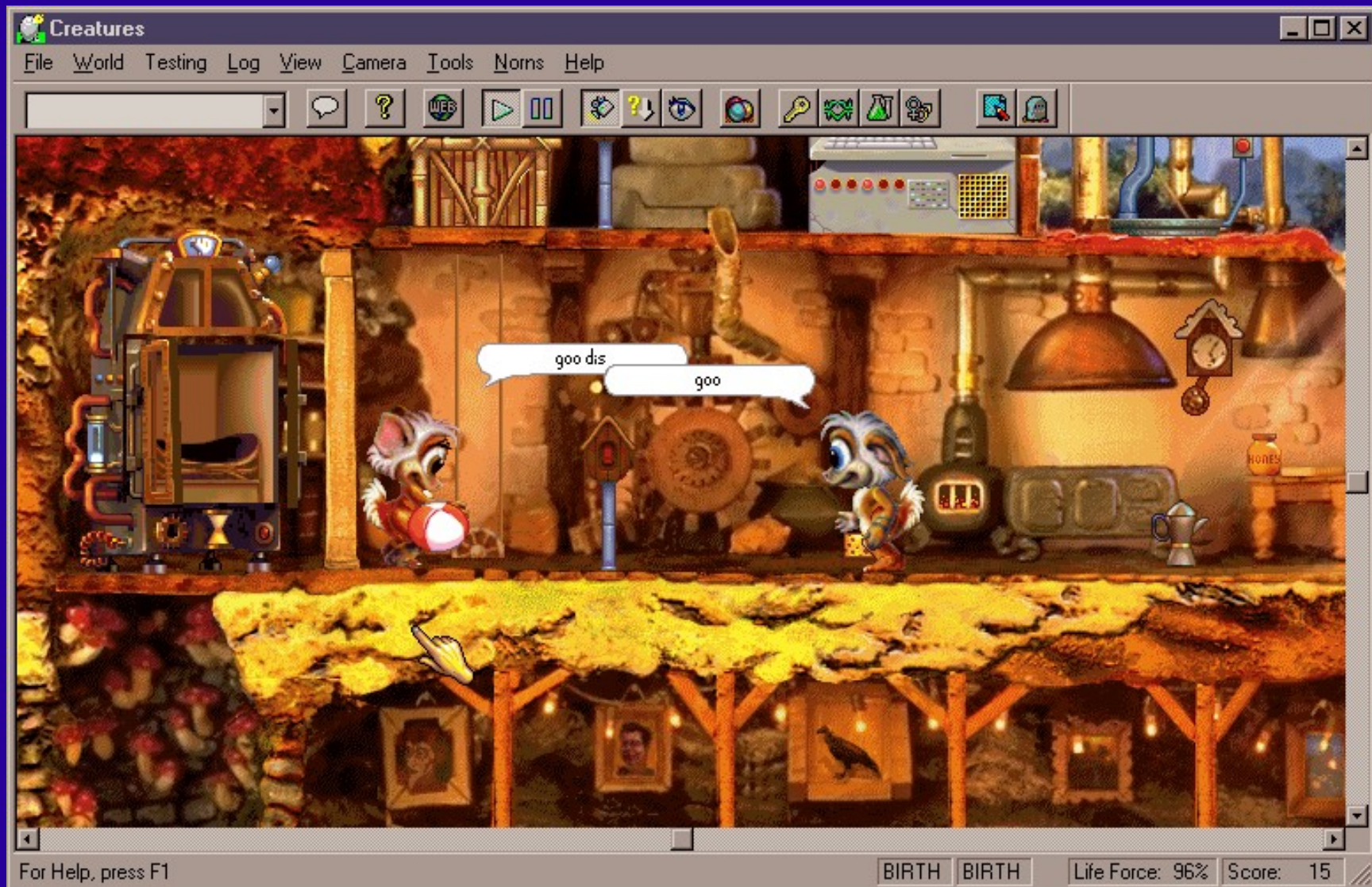
- The study of processes associated with living systems by trying to re-implement those processes in other media (a **synthetic** approach)
- Processes include:
  - Evolution (open ended), Self-organisation, Immune systems, Communication, Learning, etc.
- Media include:
  - Software, Hardware (robots), Wetware (chemical systems)
- locating **life-as-we-know-it** within the larger picture of **life-as-it-could-be** (Chris Langton)

# Learning, memory & communication

- **Creatures** games, published by Millennium Interactive & Cyberlife Ltd
- First published in Nov 1996
- Creatures 1 sold over 500,000 copies
- Creatures 2 & 3 published in 1998 & 1999
- First commercially successful game to integrate various A-life technologies, including:
  - Genetic system, Learning system, Hormonal system, Immune system, Communication, Physiology, Drives, and more...

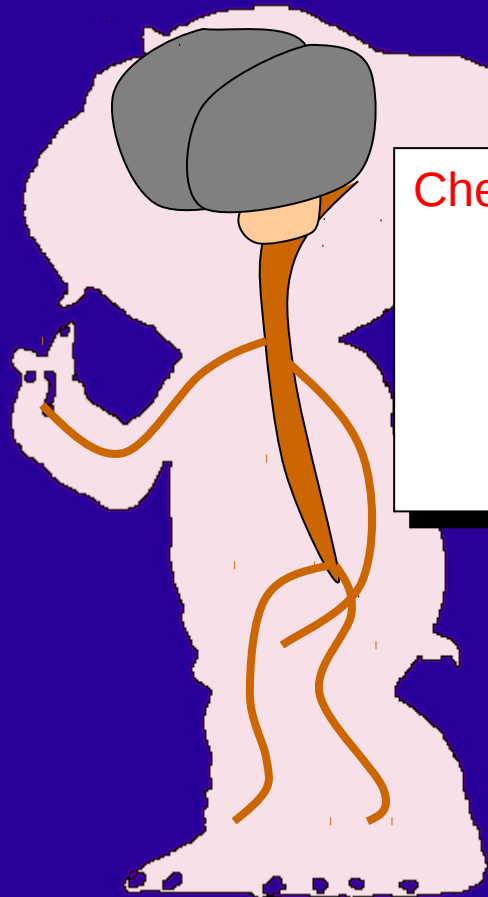


# Creatures main window [MOVIE]

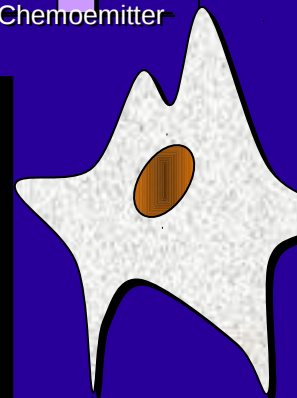
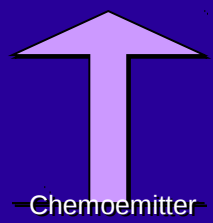


Thanks to Steve Grand for this and the following slides about Creatures

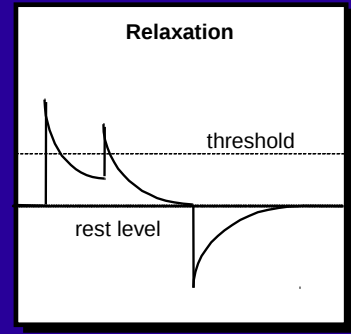
# Brain physiology



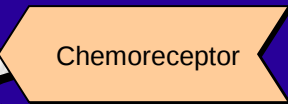
**Chemoemitter:**  
 Chemical  
 Gain  
 Rate  
 Threshold  
 Invert



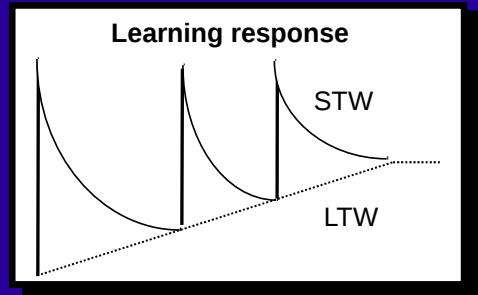
**Cell body:**  
 Output  
 Threshold  
 STATE  
 Relaxation  
 rate  
 Rest state  
 Gain



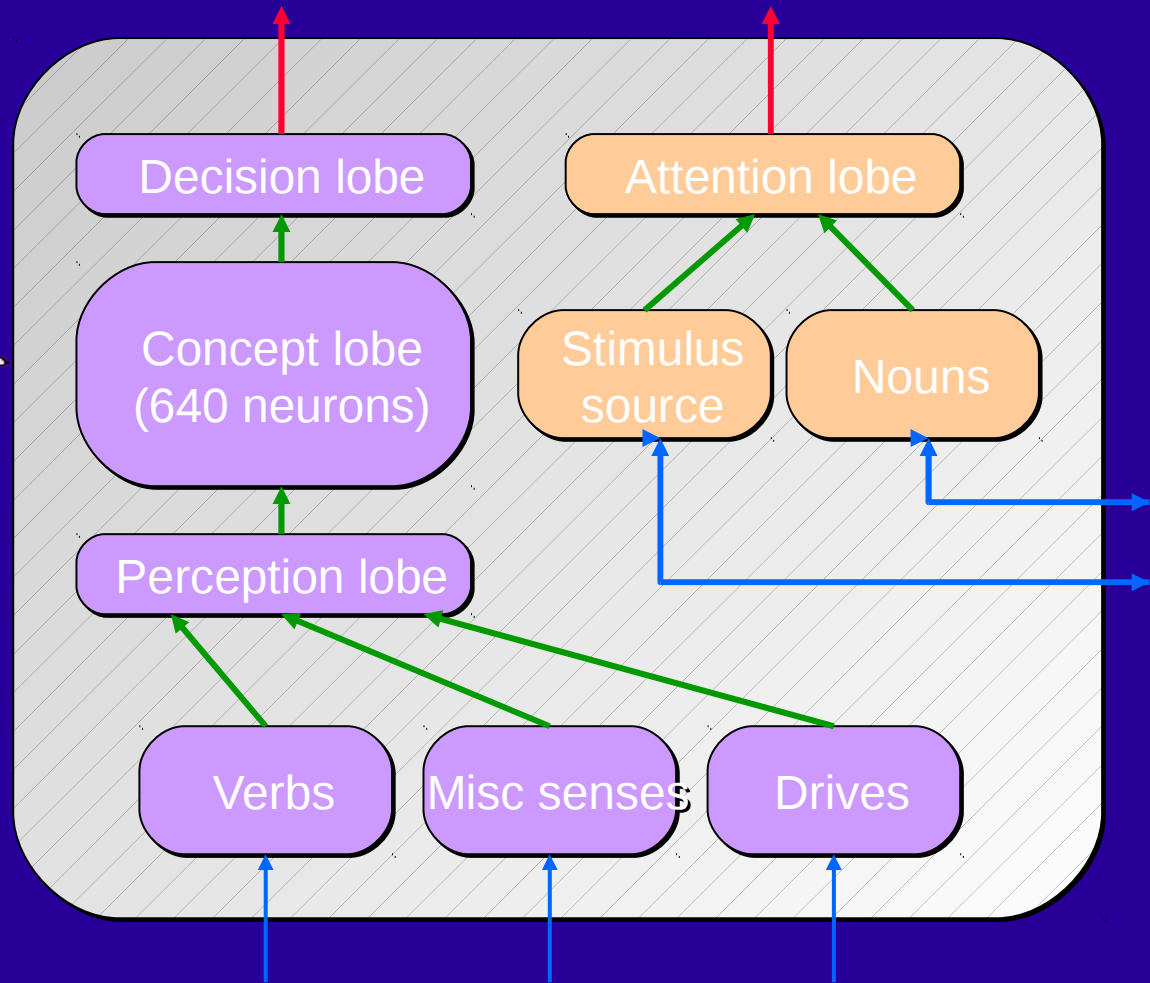
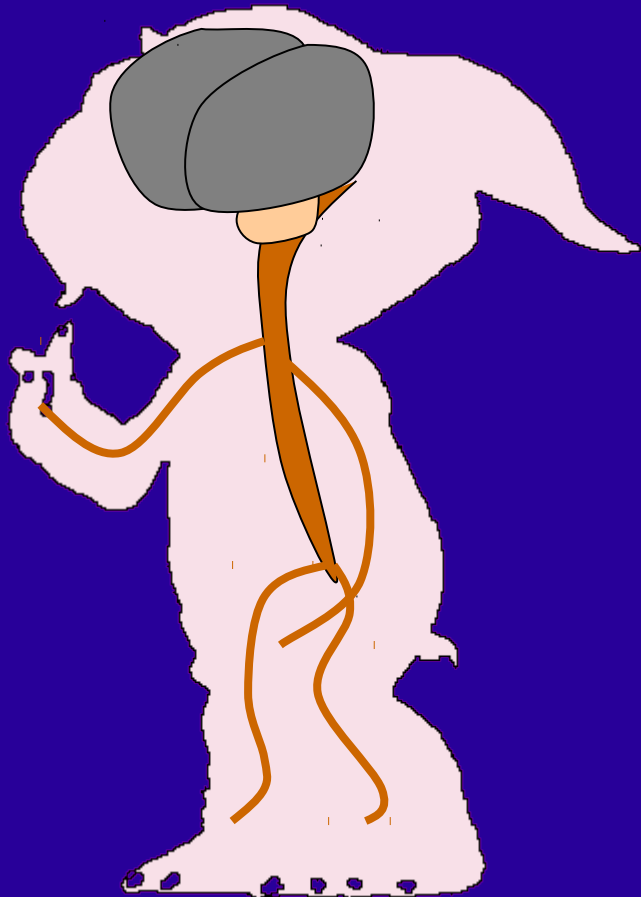
**Chemoreceptor**  
 Chemical  
 Gain  
 Nominal  
 Threshold  
 Invert  
 Digital/analogue



**Synapse:**  
 Short term wt  
 Long term wt  
 Relaxation  
 STW  
 Relaxation  
 LTW  
 Susceptibility  
 Susc  
 relaxation  
 Strength

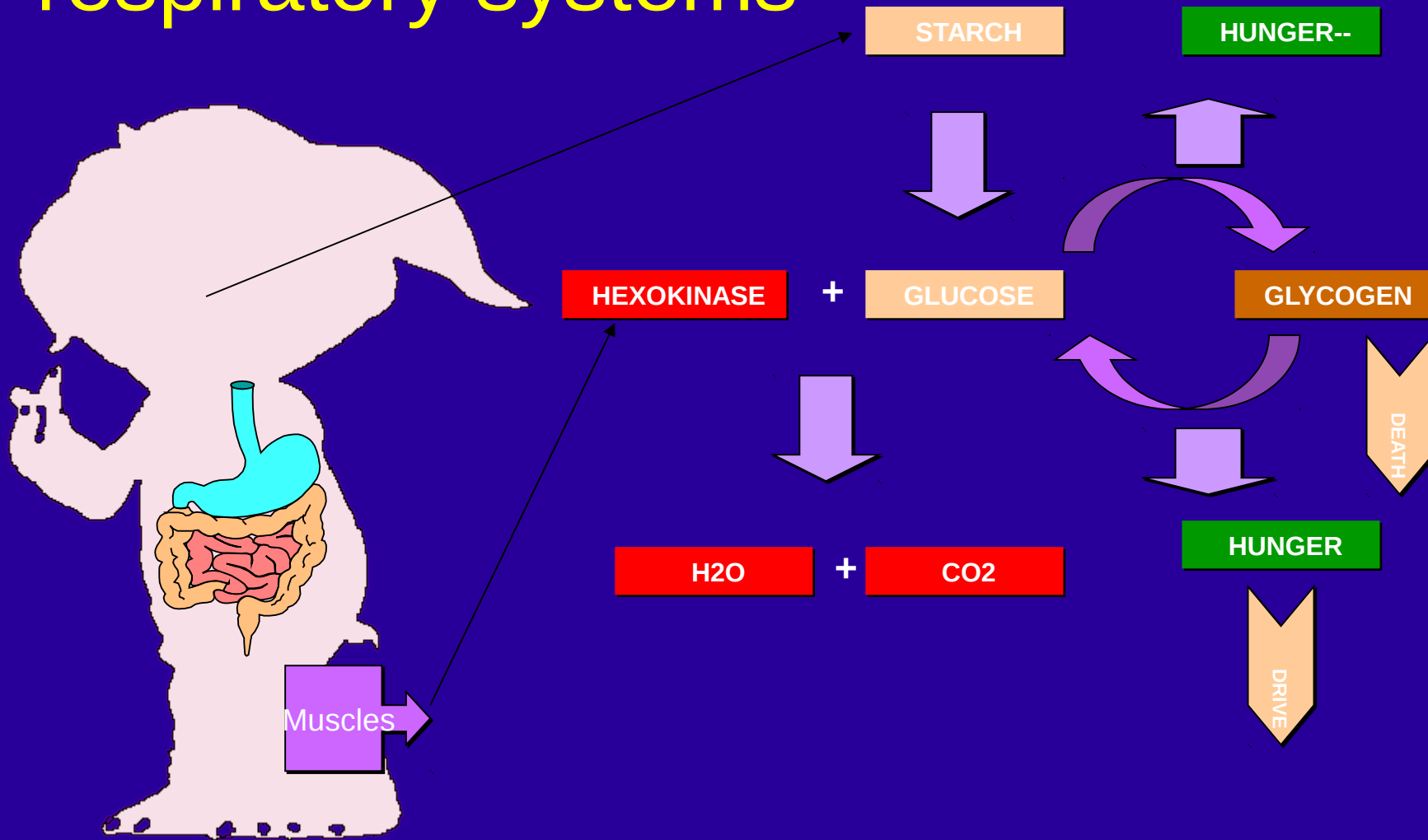


# Brain function

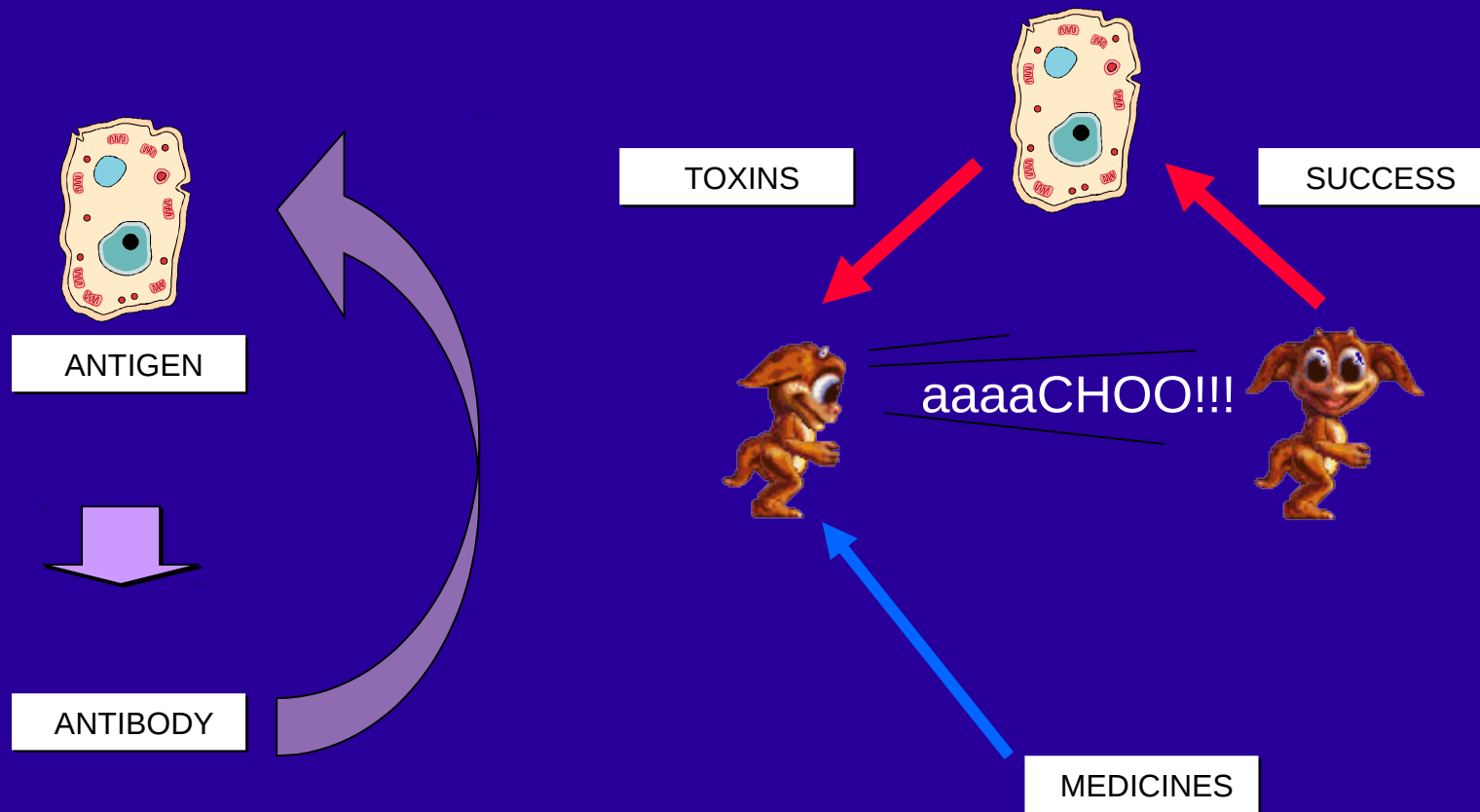




# Digestive & respiratory systems



# Bacteria & Immune system



# Creatures: some comments

- Some of the things people did with their creatures:
  - Exchanging norns
  - Worrying about them
  - Engineering cross-breeds (Grenorns)
  - Writing utilities
  - Creating new objects
- Foreshadowed much of the more recent developments in digital pets, but in many ways much more sophisticated
- Original creator of Creatures, **Steve Grand**, just starting work on a new project call Grandroids

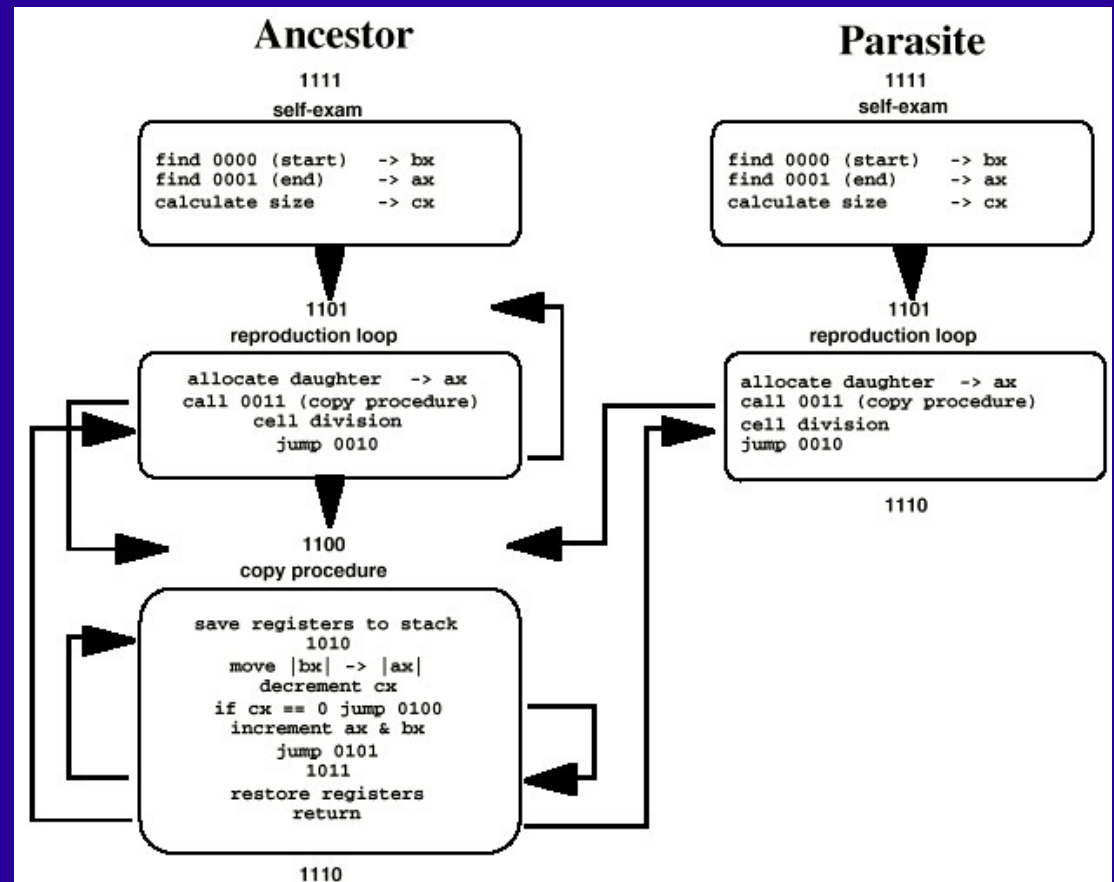
# Evolving ecosystems

- Norns and bacteria in Creatures represent a very simple evolving ecosystem
- More complex attempts at building whole ecosystems:
  - **Technosphere** (1995): Jane Prophet & Gordon Shelley
  - **Svarga** (2006), Second Life: modelled Sun, Clouds, Trees, Birds, Bees, Flowers, Bats, Glowbugs
  - **Terminus** (2007), Second Life: open scripting language



# Tierra: open-ended evolution

- A classic A-Life system (Tom Ray, 1991)
- **Self-reproducing** computer programs
- **Mutations** can produce heritable variations (and therefore evolution)
- Results include:
  - Parasites; Immunity to parasites; More efficient replication; and more
- **Open-ended evolution, creativity, complexity...**



# Future directions

- Games like NERO and GAR indicate some ways in which genetic algorithms can be integrated into mainstream games
- There is also work underway on using genetic algorithms to evolve static content such as buildings (e.g. Simon Colton's group at Imperial College)
- Much of other work discussed here is now quite old
- With the current power of PCs and continued developments in networking and web standards, there is now **huge potential for taking these ideas to a whole new level over the next few years**

# Further information

- Karl Sims work
  - <http://www.karlsims.com/evolved-virtual-creatures.html>
- Kenneth Stanley's group
  - Home page: <http://www.cs.ucf.edu/~kstanley/>
  - NERO: <http://nerogame.org/>
  - GAR: <http://gar.eecs.ucf.edu/>
- Creatures
  - [http://creatures.wikia.com/wiki/Creatures\\_Wiki\\_Homepage](http://creatures.wikia.com/wiki/Creatures_Wiki_Homepage)
  - <http://stevegrand.wordpress.com/>
- Tierra
  - <http://life.ou.edu/tierra/>
- Simon Colton's Computational Creativity group:
  - <http://ccg.doc.ic.ac.uk/>
- Biota.org (lots of useful links, papers, and podcast)
  - <http://www.biota.org/>

# Papers to read

- Karl Sims  
**“Evolving Virtual Creatures”**  
Computer Graphics (Siggraph '94 Proceedings)  
July 1994, pp.15-22  
<http://www.karlsims.com/papers/siggraph94.pdf>
- Erin J. Hastings, Ratan Guha, and Kenneth O. Stanley  
**“Evolving Content in the Galactic Arms Race Video Game”**  
Proceedings of the IEEE Symposium on Computational Intelligence and Games (CIG'09), 2009  
<http://eplex.cs.ucf.edu/publications/2009/hastings.cig09.html>