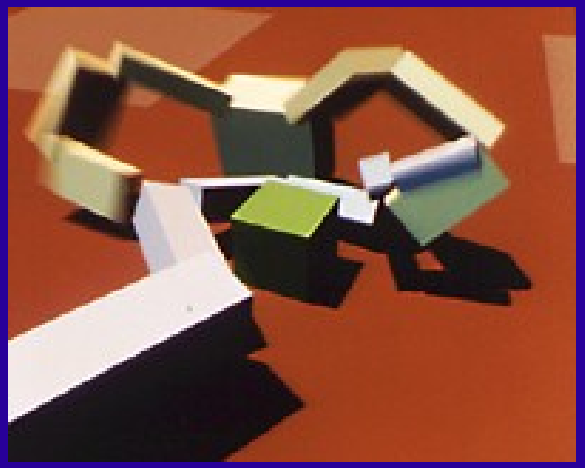
Genetic Algorithms, Artificial Life and Computer Games



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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

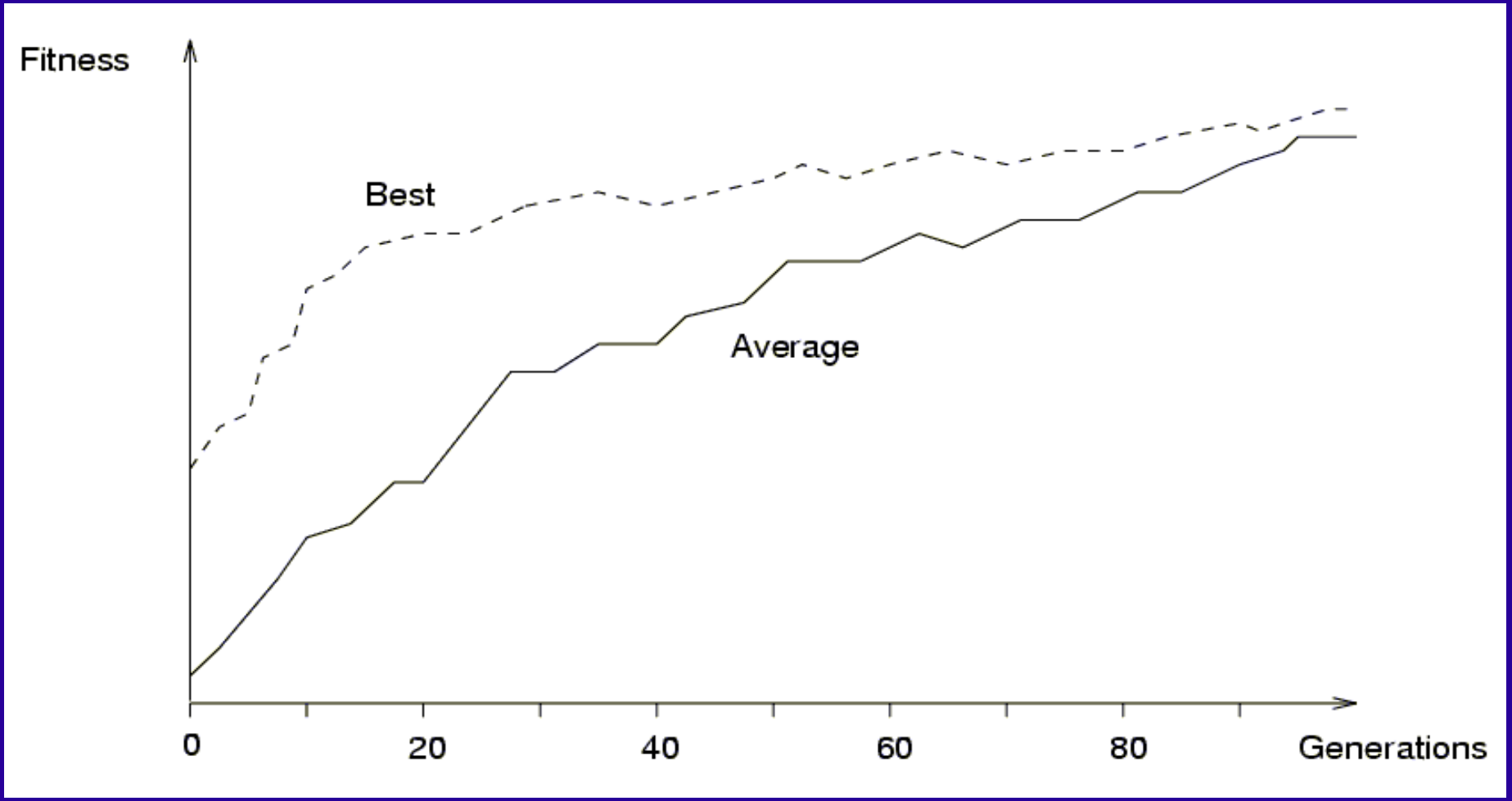
Genetic Algorithm Pseudocode

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

Pseudocode from http://www.cs.unibo.it/babaoglu/courses/cas/slides/GA.pdf

GA: example of convergence



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

GA example: evolution of walking

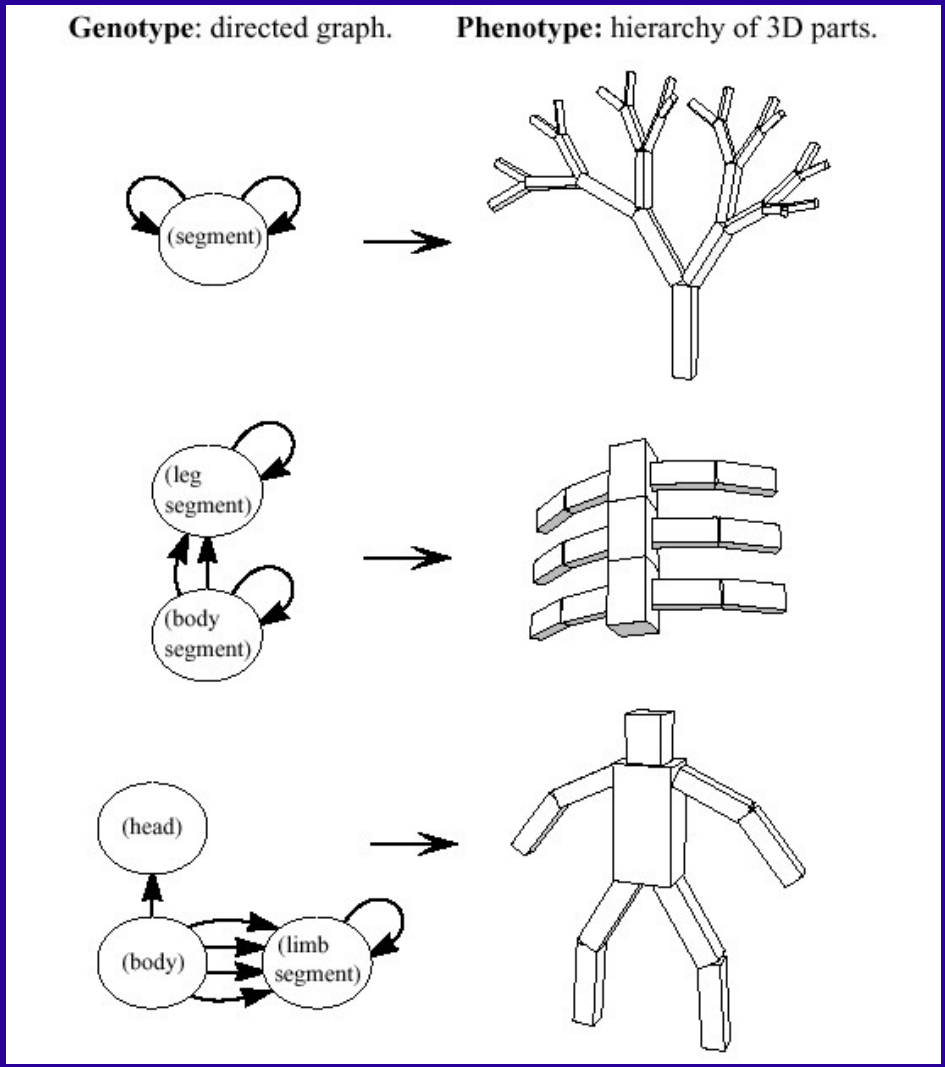
- Example application by NaturalMotion Ltd, 2002:
- Model a creature (e.g. human) in a 3D virtual environment with simulated physics
- Use a genetic algorithm to evolve a controller for the creature's limb movement
- [MOVIE]

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 ⇒ NaturalMotion ⇒ Holywood

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)

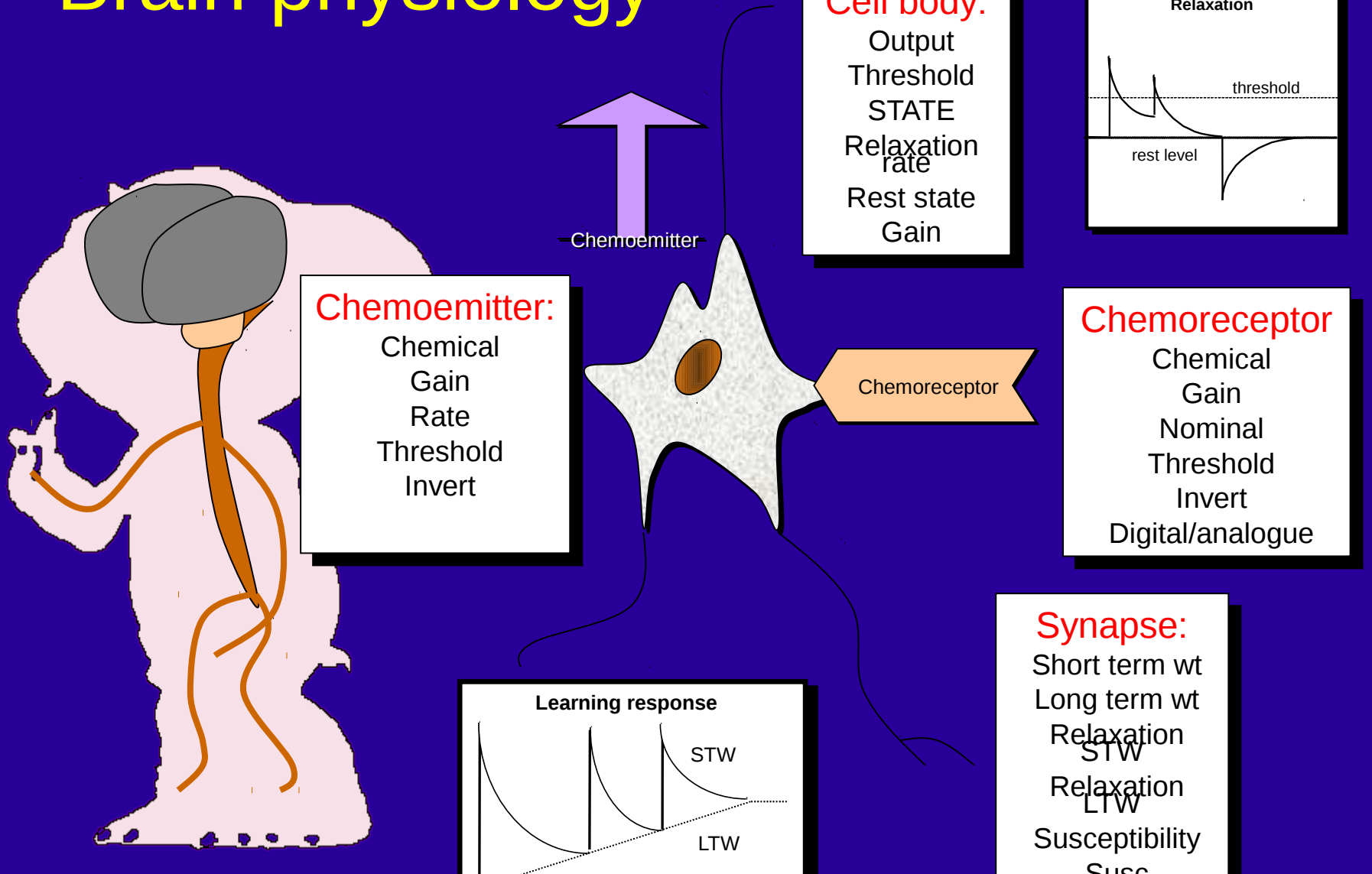
Learning, memory & communication

- **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



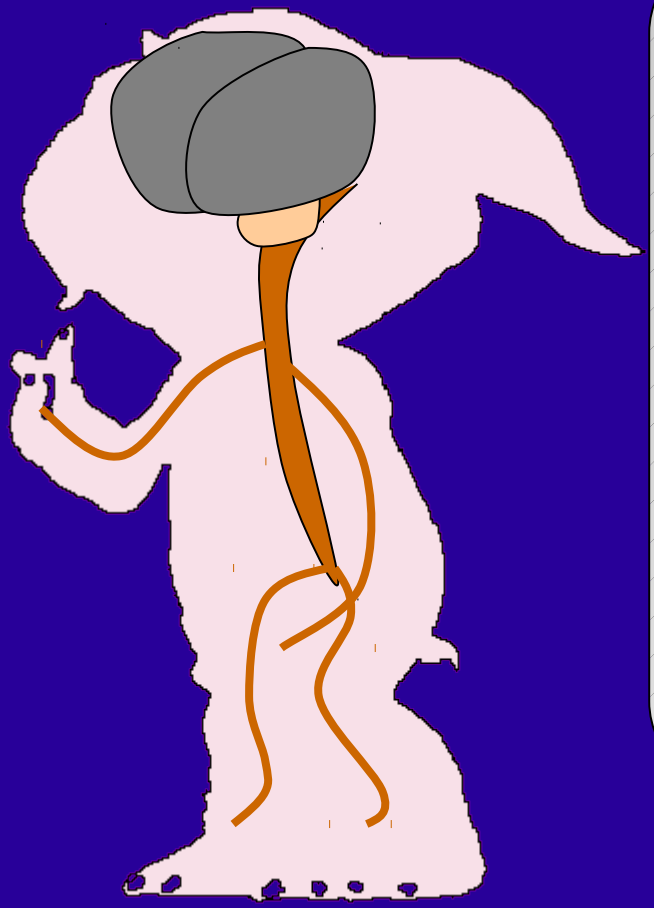
Cell body:
Output
Threshold
STATE
Relaxation rate
Rest state
Gain

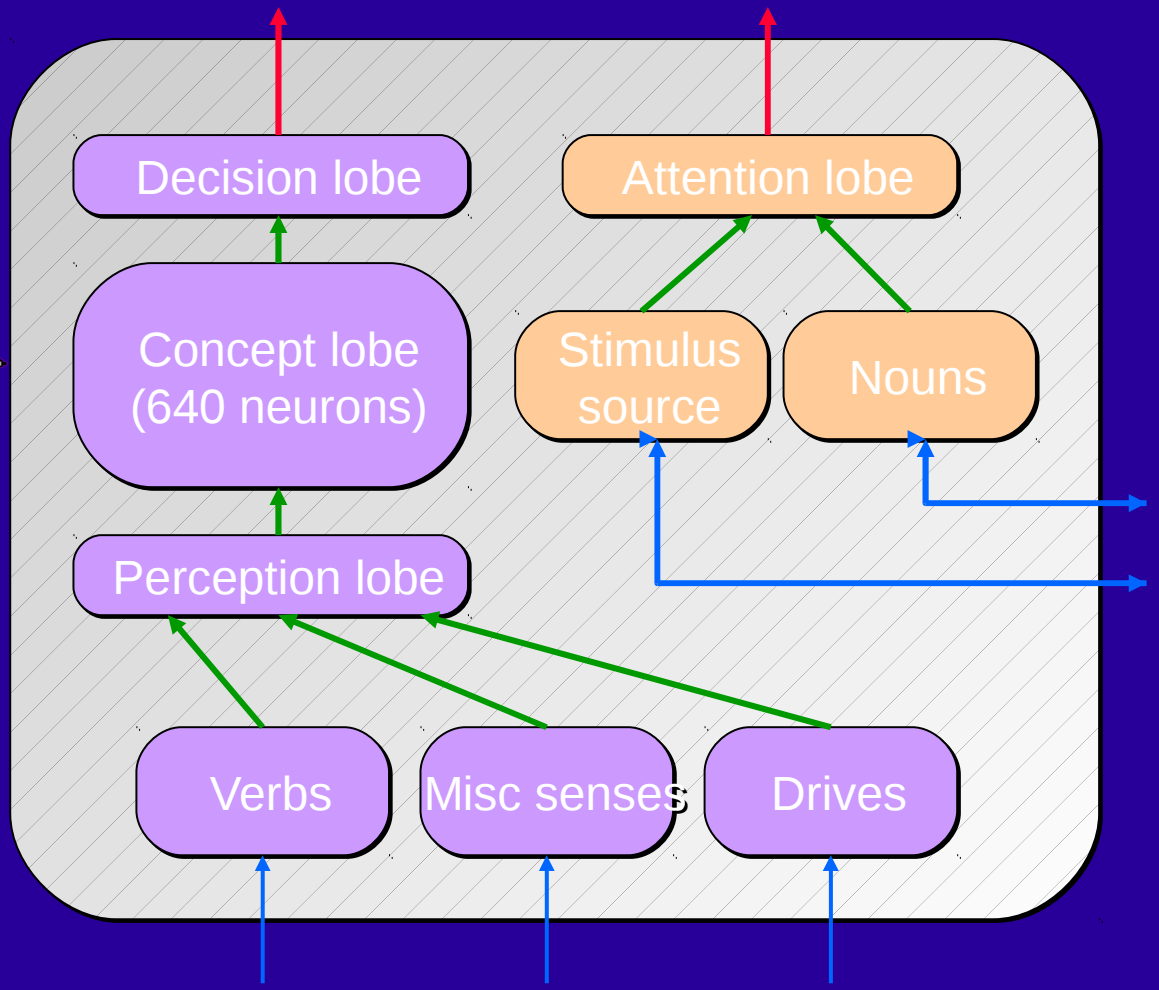
Chemoemitter:
Chemical
Gain
Rate
Threshold
Invert

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





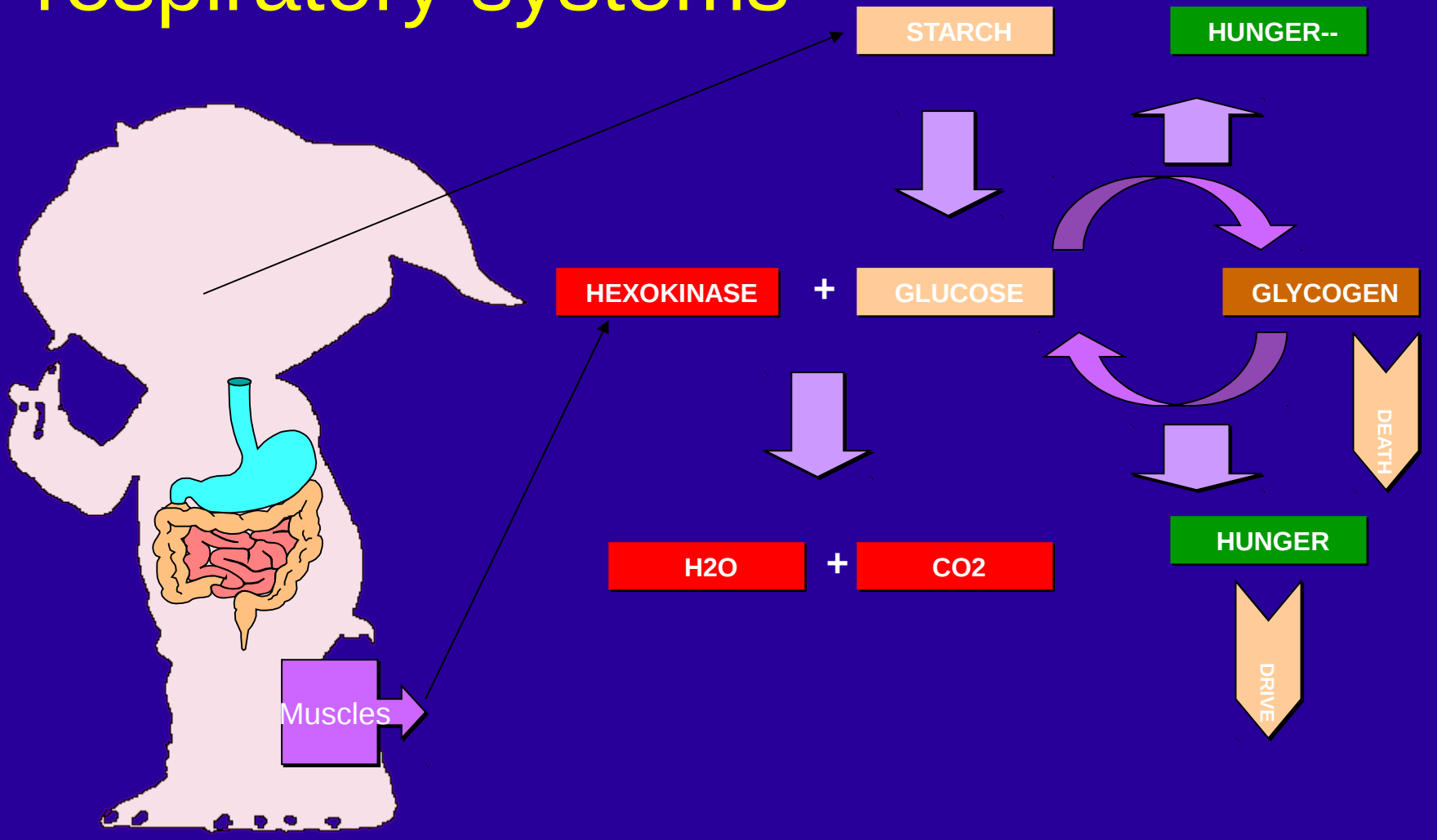
Control of drives

Food → Hunger

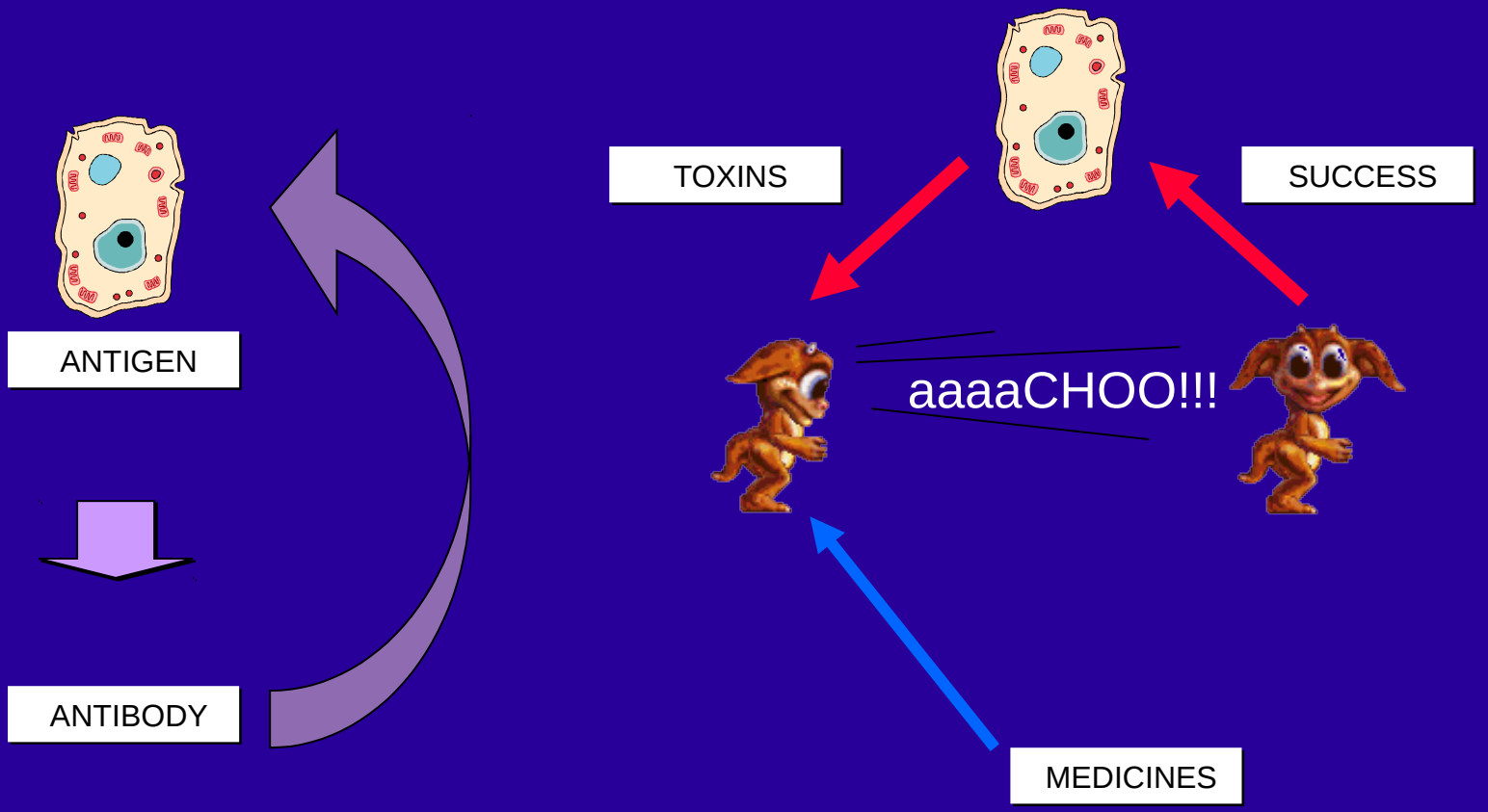
Activity? ⋯→ Boredom

??? ·—·—·—→ Anger

Digestive & respiratory systems



Bacteria & Immune system



Creatures: some comments

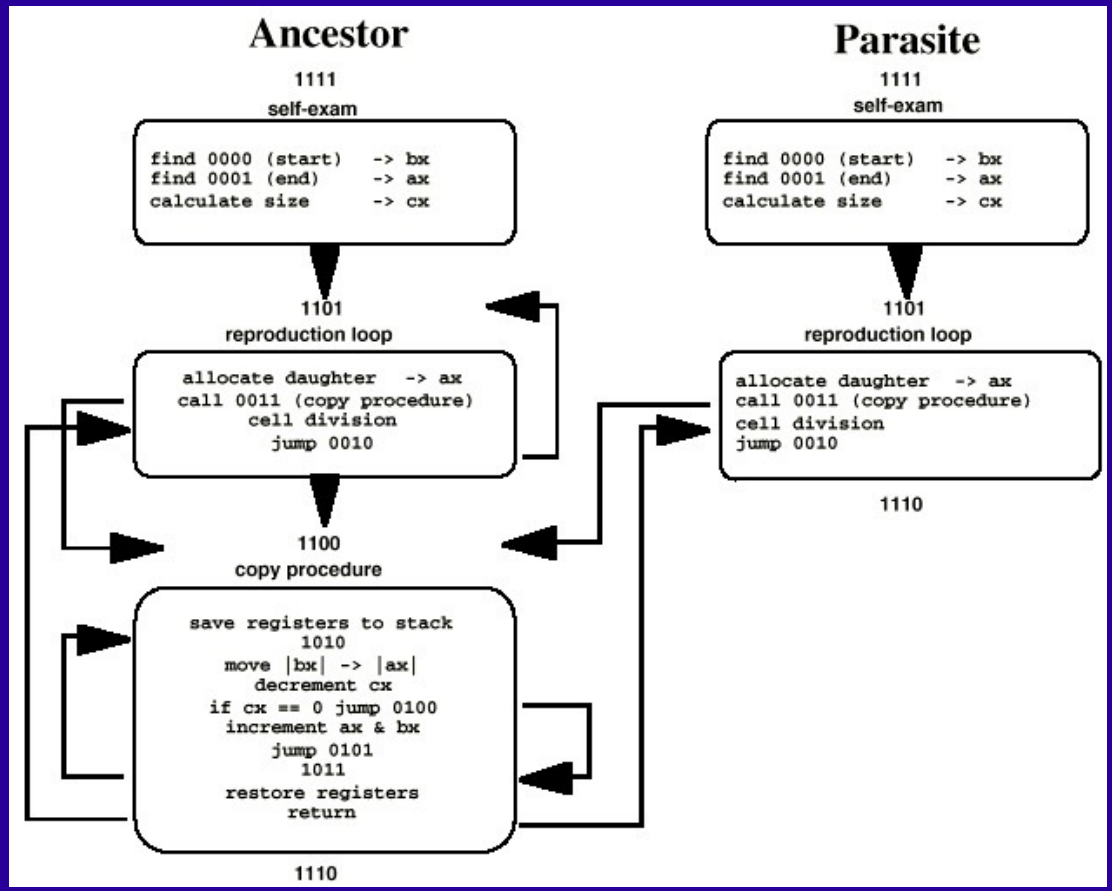
- Some of the things people did with their creatures:
  - Exchanging norns
  - Worrying about them
  - Engineering cross-breeds (Grenorns)
  - Writing utilities
  - Creating new objects
- Foreshadowed much of the more recent developments in digital pets, but in many ways much more sophisticated
- Original 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://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