

# Homeostasis and Long-term Autonomy in Multi-Robot Systems

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# Introduction

- 2005-2009:
  - University of York
  - Undergraduate master's in Computer Science (MEng)
  - Final year master's project with Jon Timmis
- 2009-2012:
  - PhD in Electronics and Electrical Engineering
  - Part of the SYMBRION project
  - Supervised by Jon Timmis and Andy Tyrrell

# Homeostasis and Long-term Autonomy

- Long-term autonomy
  - The ability of a system to survive for long periods of time without human intervention
  - Applications: space exploration, search and rescue
  - Requirements: adaptability, fault tolerance, efficiency
- Homeostasis
  - Example: Thermoregulation
  - Provided by Immune, nervous and endocrine systems
  - Could help satisfy the requirements for long-term autonomy

## Homeostasis

*“The tendency toward a relatively stable equilibrium between interdependent elements, esp. as maintained by physiological processes.” [1]*

# Master's Project

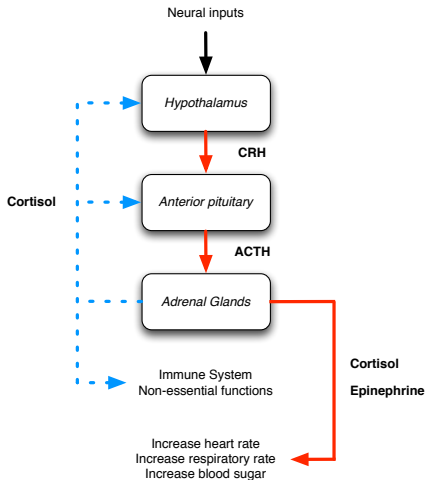
## Neuroendocrinology

*"Having to do with the interactions between the nervous system and the endocrine system."* [4]

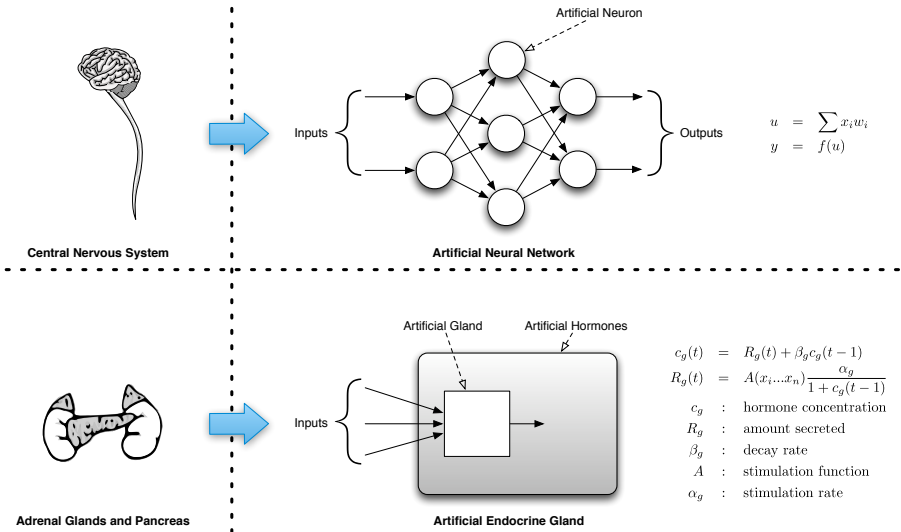
- A Neuroendocrine Architecture for the Control of Multiple Robots
- Bio-*inspired*, behaviour-based, swarm robotics project
- Neuroendocrine Control Architecture:
  - Originally developed by Mark Neal and Jon Timmis [2, 3]
  - Motivated by homeostasis
  - Inspired by the nervous and endocrine systems
  - Extended Artificial Neural Network (ANN)
- Simulated robots
- Applied to a swarm foraging task

# Biological Neuroendocrine Systems

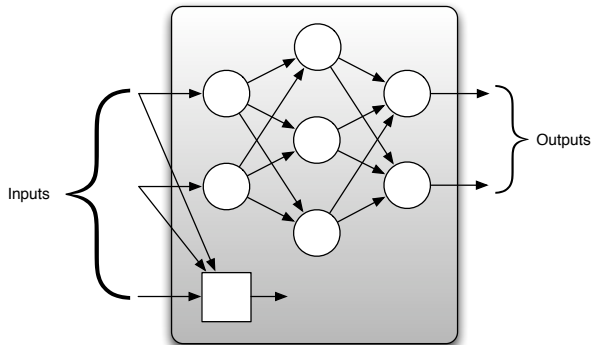
- The endocrine system
  - Glands
  - Hormones
  - Cell-hormone receptors
  - Cell-hormone response
- Example: The stress response
  - HPA-axis
  - CRH-ACTH-Cortisol sequence
  - Prepares the body for stressful situations
  - Long-loop negative feedback



# Artificial Neuroendocrine Control Architecture I



# Artificial Neuroendocrine Control Architecture II

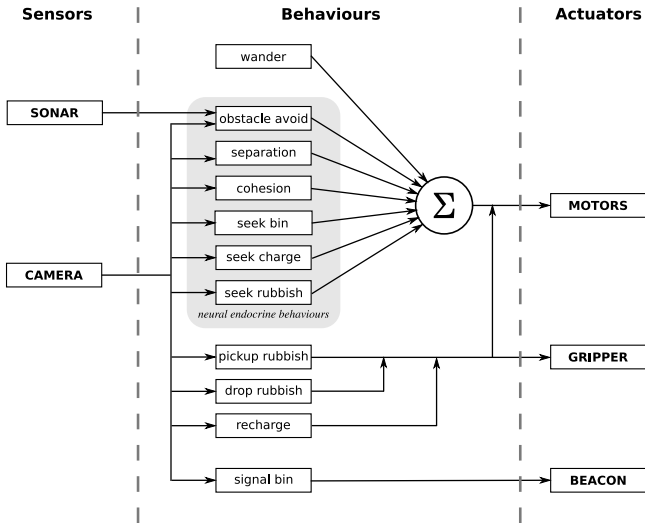


Artificial Neuroendocrine Network

$$u = \sum x_i w_i \sum c_g s_{ig}$$
$$y = f(u)$$

$$c_g(t) = R_g(t) + \beta_g c_g(t-1)$$
$$R_g(t) = A(x_i \dots x_n) \frac{\alpha_g}{1 + c_g(t-1)}$$

# Control System Overview





# Foraging Robots

(Video not included)

# Symbiotic Evolutionary Robot Organisms

- 5 Year EU Project
- Swarm and reconfigurable robotics
- Sharing of power and computational resources
- “100 Robots 100 Days”
- Immune-inspired:
  - Fault tolerance
  - Energy homeostasis
  - Power management








# Thanks!



Any questions?

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# Bibliography I

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-  Mark Neal and Jon Timmis, "Timidity: A Useful Emotional Mechanism for Robot Control?" *Informatica - special issue on perception and emotion based control*, vol. 27(2), 2003, pp 197-204.
-  Mark Neal and Jon Timmis, "Once More Unto the Breach: Towards Artificial Homeostasis." *Recent developments in biologically inspired computing*, 2005, pp 340-365.
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<http://www.medterms.com/script/main/art.asp?articlekey=33442>.
-  Leandro N. De Castro and Jonathan Timmis, *Artificial immune systems: a new computational intelligence approach*. London: Springer, 2002.

## Bibliography II

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-  Ronald C. Arkin, *Behavior-based Robotics*. Cambridge, MA, USA: MIT Press, 1998