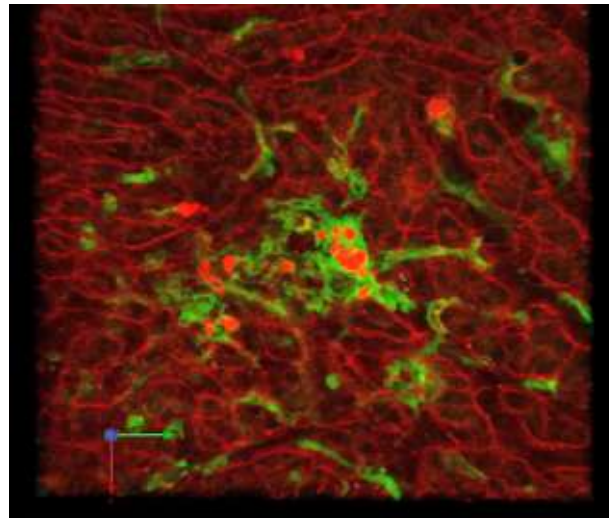# How to vaccinate a robot

Professor Jon Timmis

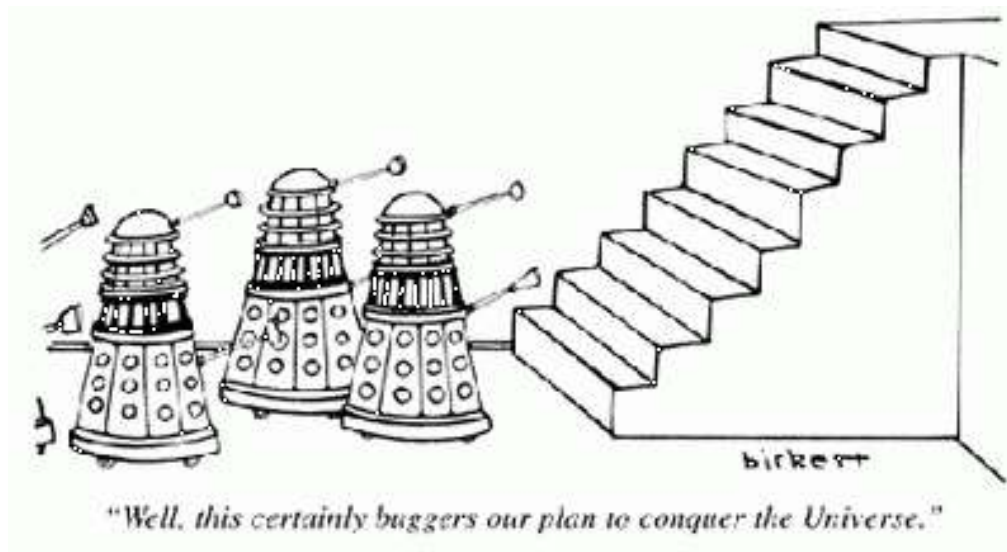Department of Electronics
YCCSA

Intersection of Engineering and Immunology

- Two main interests:

    - The development of models and simulations to aid the understanding of immune function

    - The development of intelligent and adaptive systems, with a focus on robotics (swarms)

- Very interested in how we bridge these two areas together

- Working through YCCSA has provided this opportunity

Biology has some interesting things going on ..

Interesting challenges in robotics

"Well, this certainly buggers our plan to conquer the Universe."

IN CASE OF DALEK
USE STAIRS
(THAT'S IF YOU THINK IT WILL DO ANY GOOD!)

- More seriously ...

  - Using robots in real world settings

  - Continued operation

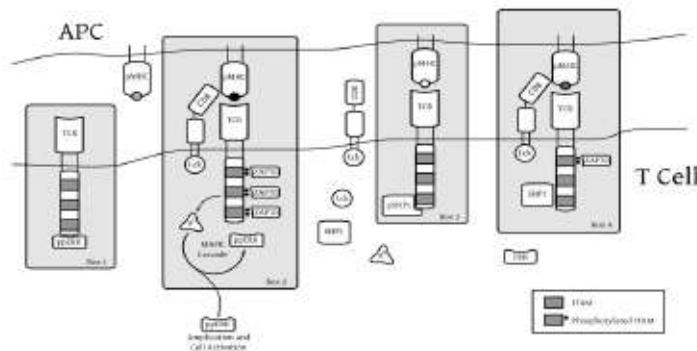# Facing these challenges with a bio-inspired approach

- A major one is the interface between the life and physical sciences

    - In my case immunologists

- Takes years to develop common language, trust and understanding

- We can learn from biology and biology can learn from us
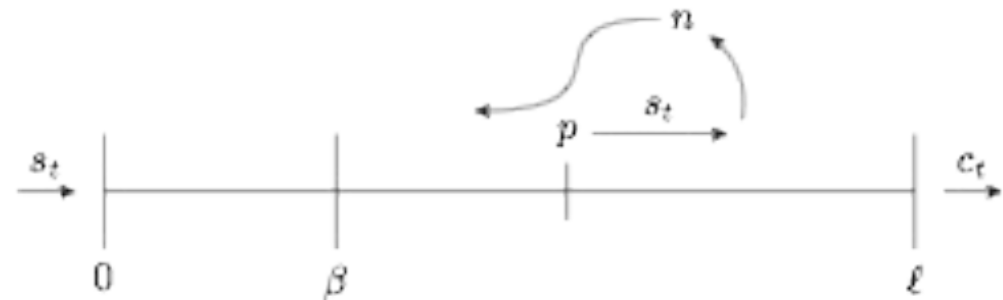
Modelling helps to inform

- Learnt to better our interaction through a principled process
  - EPSRC funded CoSMoS project
- Model can inform the biology, but inform the engineering
- We will now look at
  - T cell signalling
  - T cell recruitment in disease ...
  - ... and how T cells can be useful to engineers

Chemical Agent Detection

- There are certain markers for IED's that are helpful in their identification – Anomaly detection

- T-cells of the immune system are very good at detecting small changes

  - Natural analogy with requirements for detection
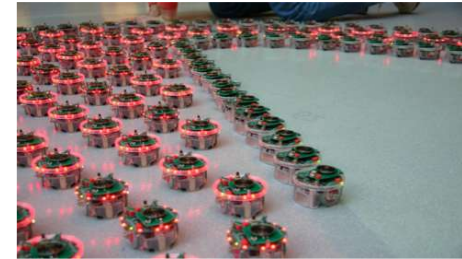
T Cell signalling

"T Cell" receptor

On-going collaboration with Dstl
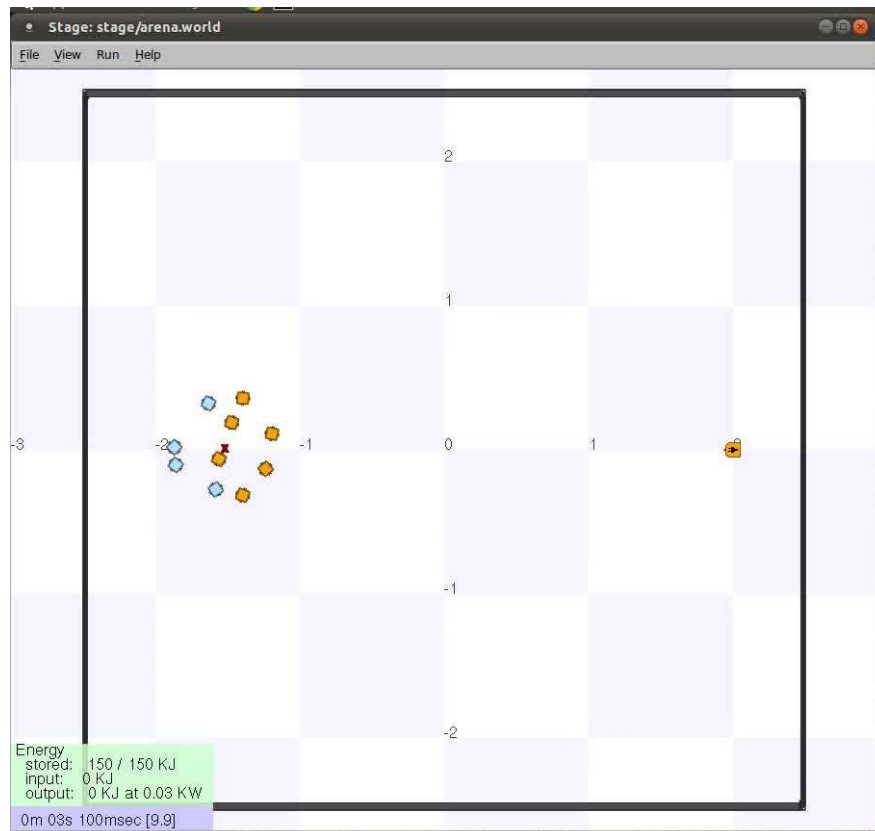
'Field' Experiments

Swarm Robotics ..

- Co-ordination of robot systems containing many agents

- Decentralised control of multiple autonomous devices

- The swarm needs to survive

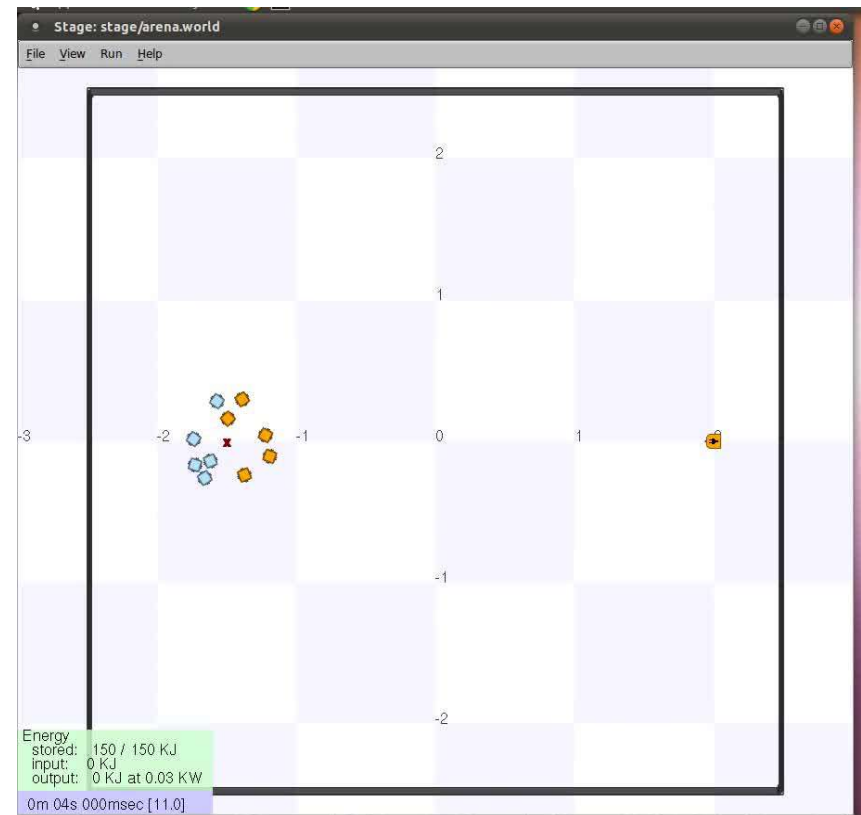 - We can think of *swarm immunity*
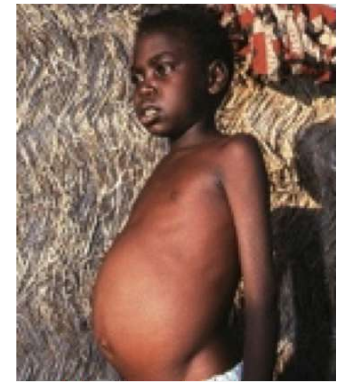
Aggregation
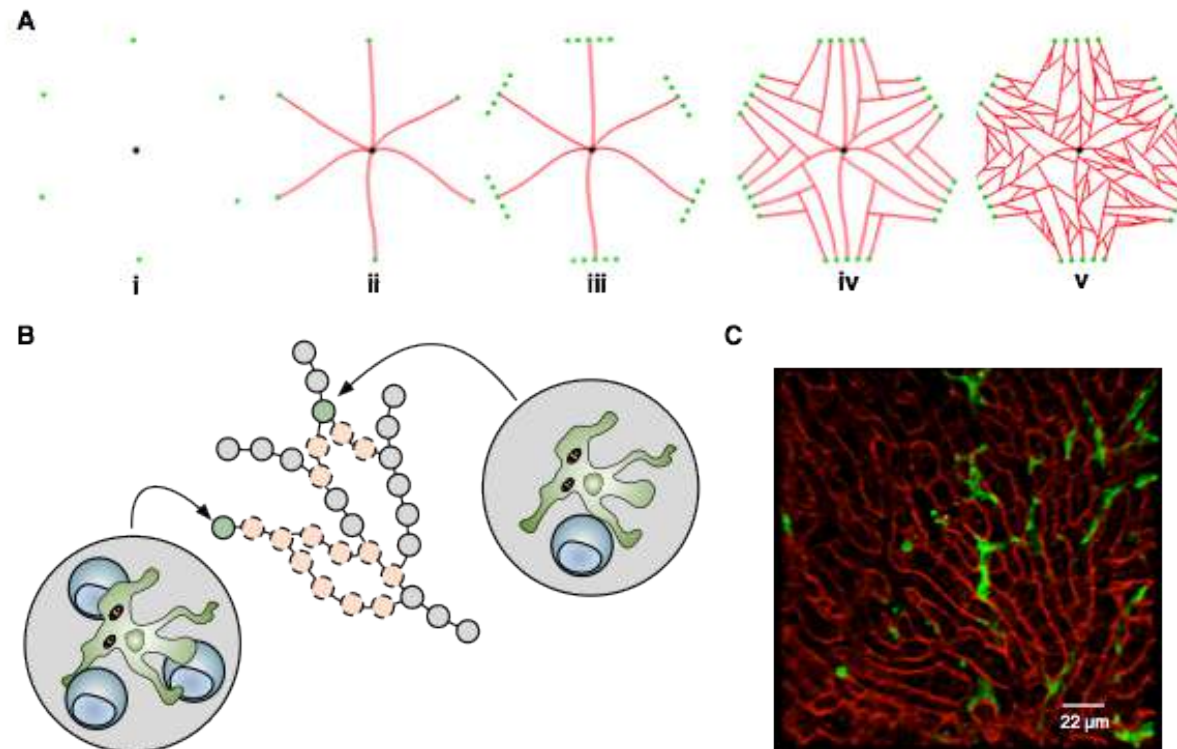
Taxis

Leave one behind?

Aggregation and Repair: Immune System style

- Visceral Leishmaniasis (VL)

- Estimated annual global incidence of 202-389k

- Causes multi-cellular aggregations in the liver called granulomas

- Mechanisms underpinning the formation of granulomas are poorly defined

- Understanding the underlying mechanisms of their formation could advance our understanding of various inflammatory disorders

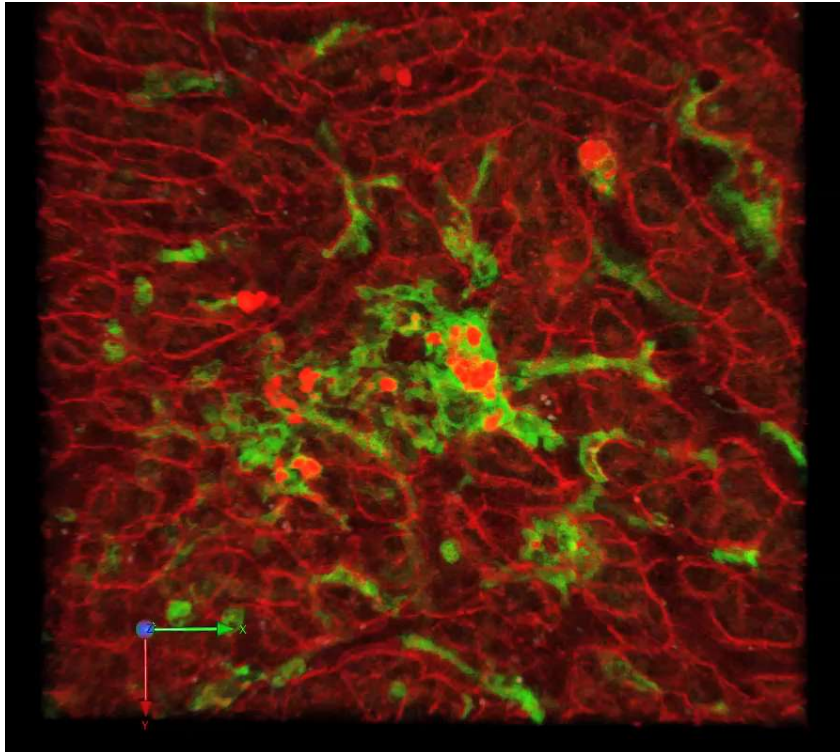www.sciencephoto.com/media/259267/enlarge

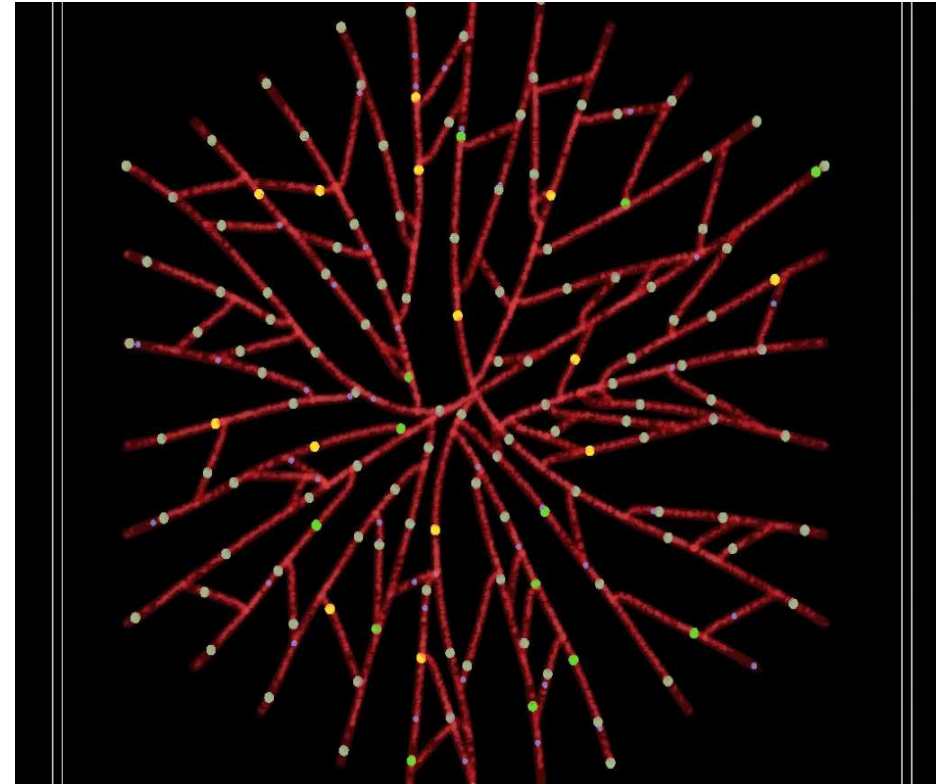# Agent-based model

Computational Liver Representation

Sinusoidal structure generation stages (a)
Computationally efficient, discrete tree-node structure (b) to mimic structure observed in live mice (c)
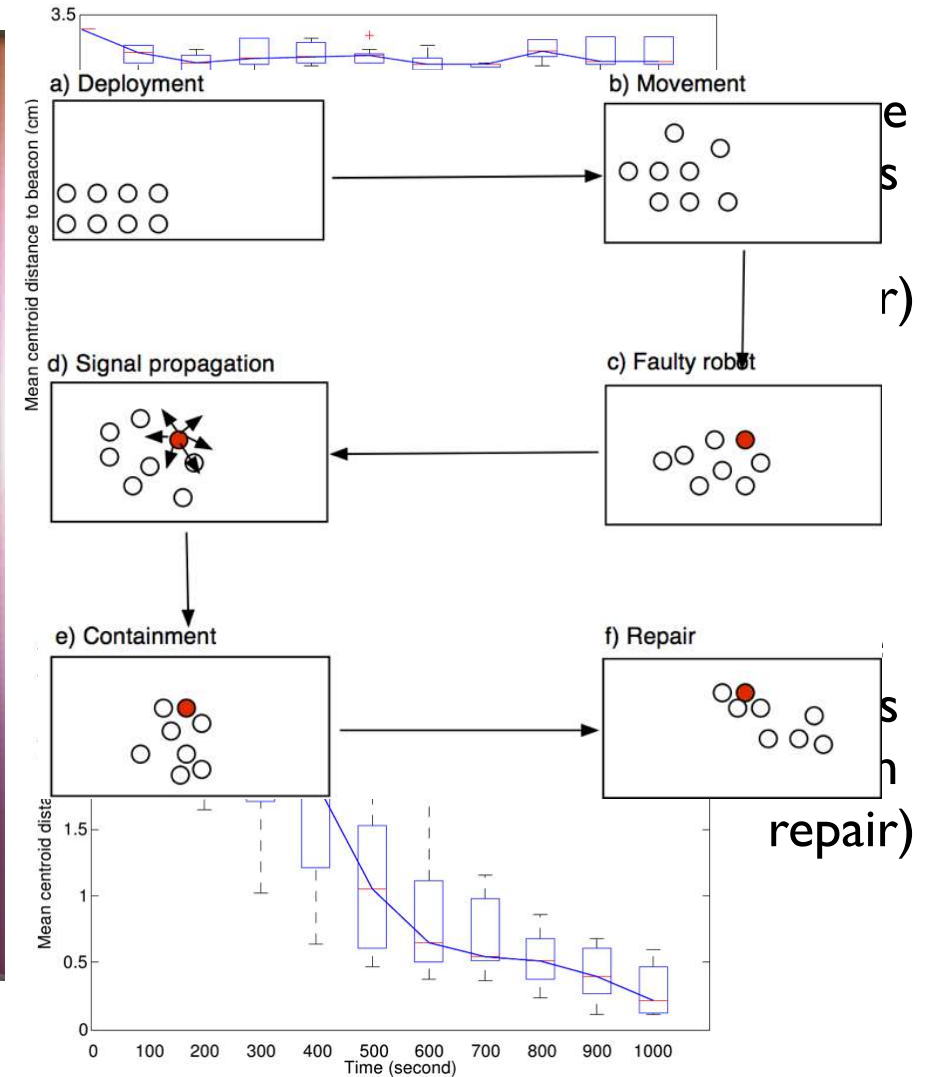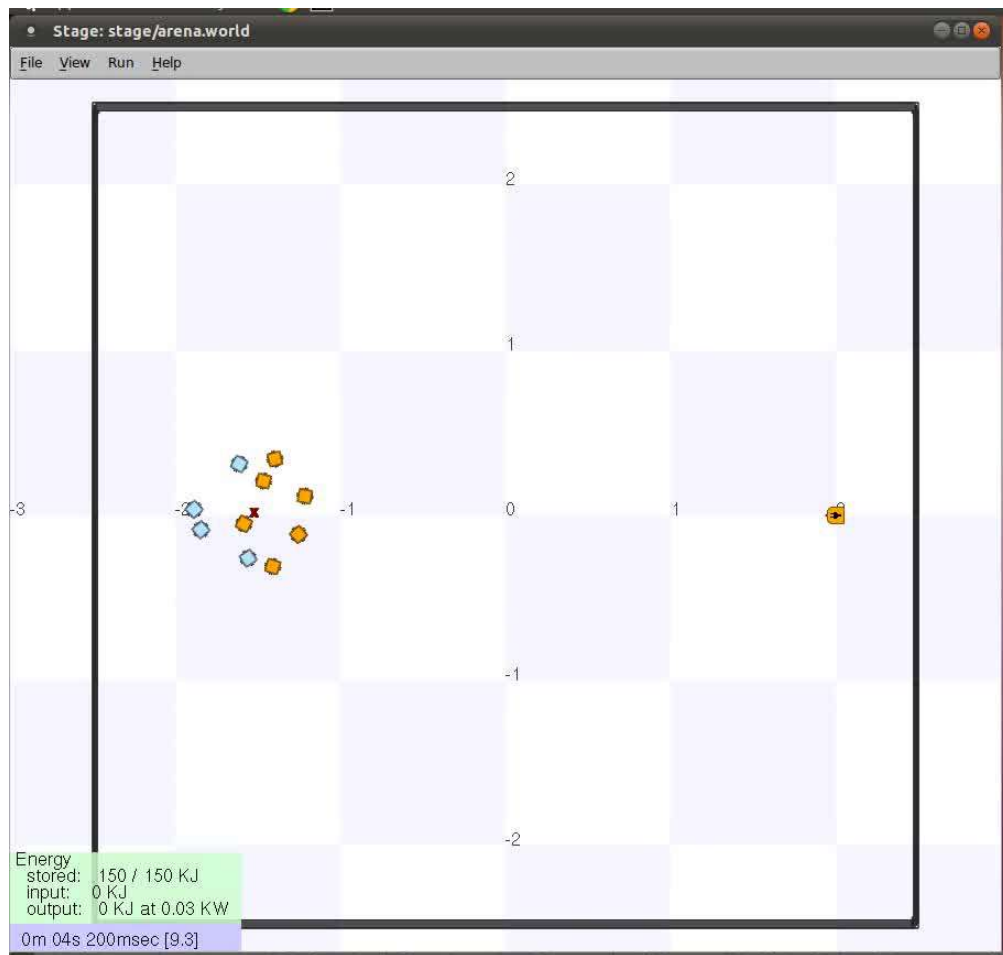
Formation of Granulomas

In vivo

In silico

We found that the promotion of a certain cytokines (regulators) promotes NKT Cells and this provides the catalyst for formation
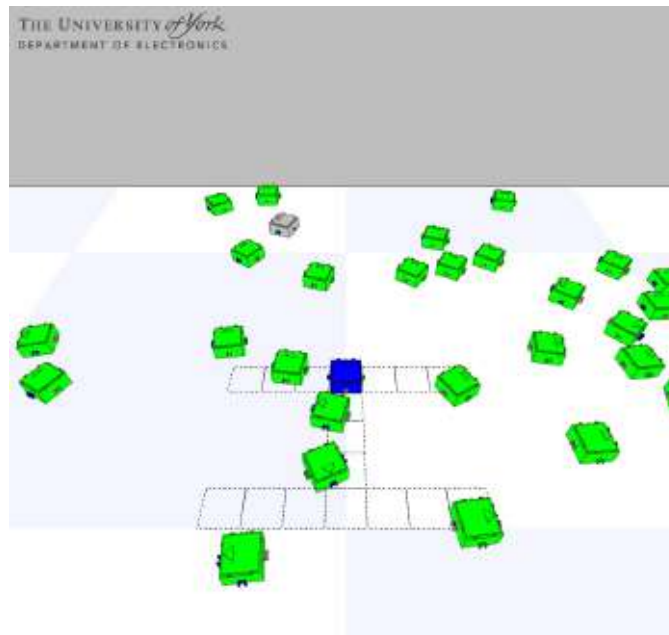This was verified with experiments in vivo where the same observation was made
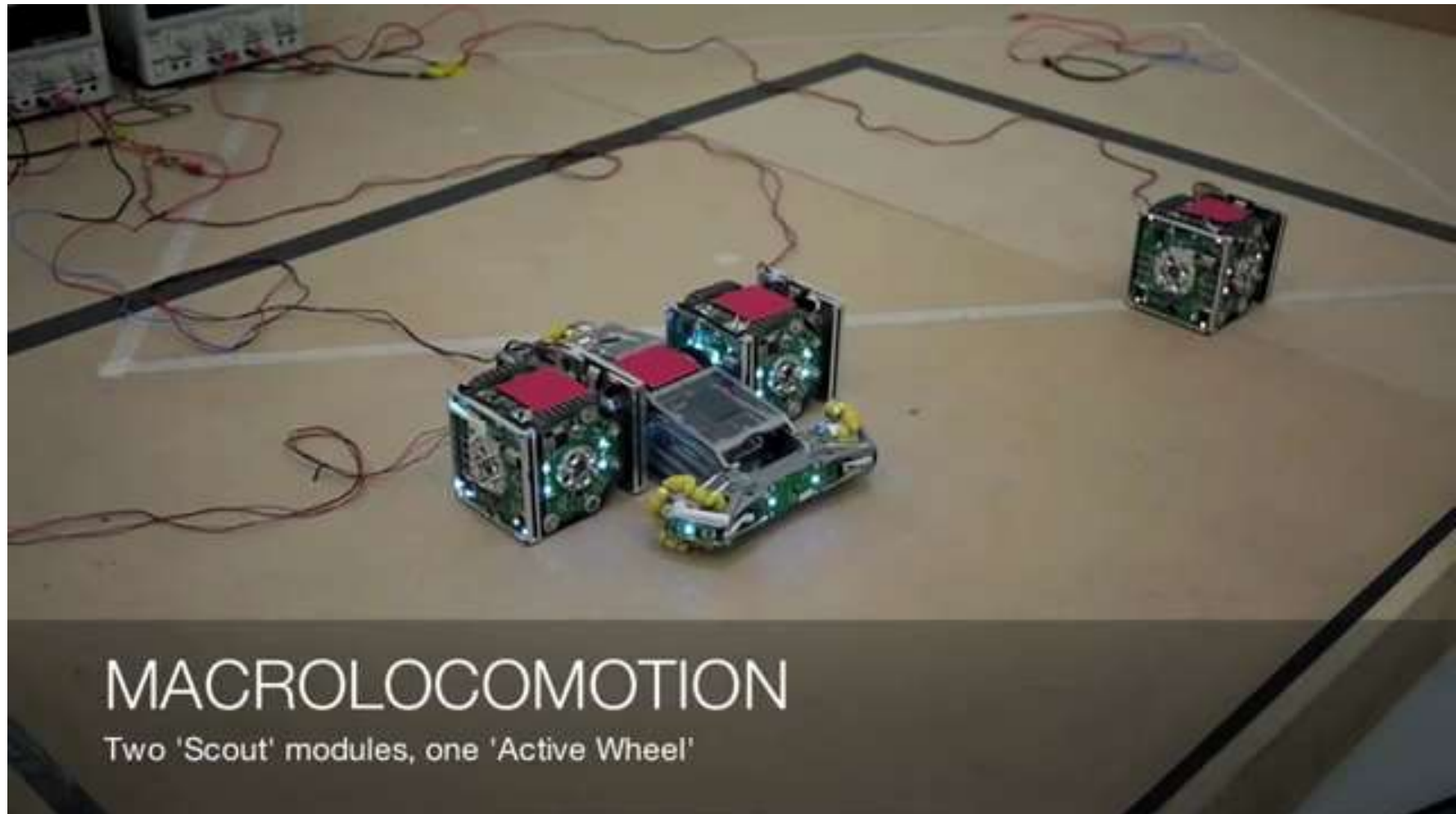
Collective repair

Modular Robotic Systems

- Like swarms (ish), but these can join together

- What happens if some robots fail when they are part of an organism?

THE UNIVERSITY of York
DEPARTMENT OF ELECTRONICS

Modular Assembly and Repair

MACROLOCOMOTION

Two 'Scout' modules, one 'Active Wheel'

Lessons learnt???
Define problem, common language

First conversation ..

–"We have about 4 cells and a few interactions …" (Kumar)

–"That should be quite easy … " (Timmis)

• The realisation of complexity

–"It is a bit harder than we first thought .." (Timmis)

–"mm, I thought so .. " (Kumar)

• After three years, many visits, conference calls and ibuprofen ....

–We have a model/simulation that we think is OK

Summary

- Interdisciplinary work where one area feeds the other

- An exciting area in which to work

- Provides novel insights into complex problems

- We have highlighted only a few examples today