

Motivation

- to demonstrate how modelling the development of granuloma formation can provide useful insight into the understanding of its properties
- to propose a self-healing swarm robotic systems inspired by granuloma formation

Granuloma Formation

Granuloma formation is a compact (organised) collection of mature mononuclear phagocytes (macrophages and/or epithelioid cells) which may or may not accompanied by accessory features such as necrosis of the infiltration of other inflammatory leukocytes [1]. Some of the cells involved in granuloma formation [2]

- macrophages
- tumor necrosis factor cells
- natural killer cells
- T-cells

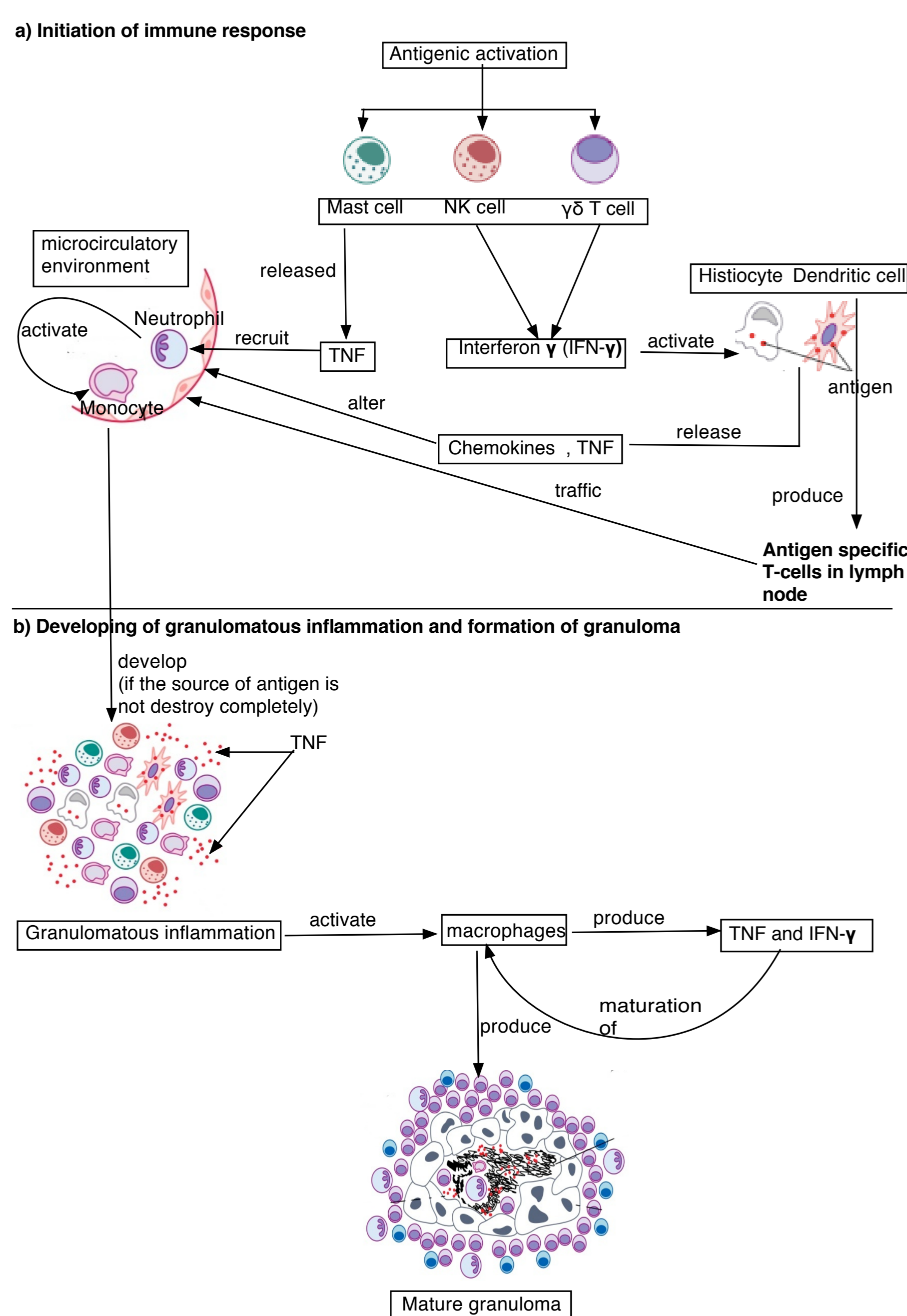


Figure: Morphology of various elements of mononuclear phagocytes system (upon initiation of immune response to infection)[2]

The Simplified Agent-Based Model

Our simplified model of granuloma formation using NetLogo [3] contains the following agents:

- uninfected macrophages
- infected macrophages
- T-cells
- cytokines

Cytokine agents act as a proxy. They direct T-cells and uninfected macrophages towards the site of infection. The infections themselves are not physically represented except by the presence of an infected macrophage in the model.

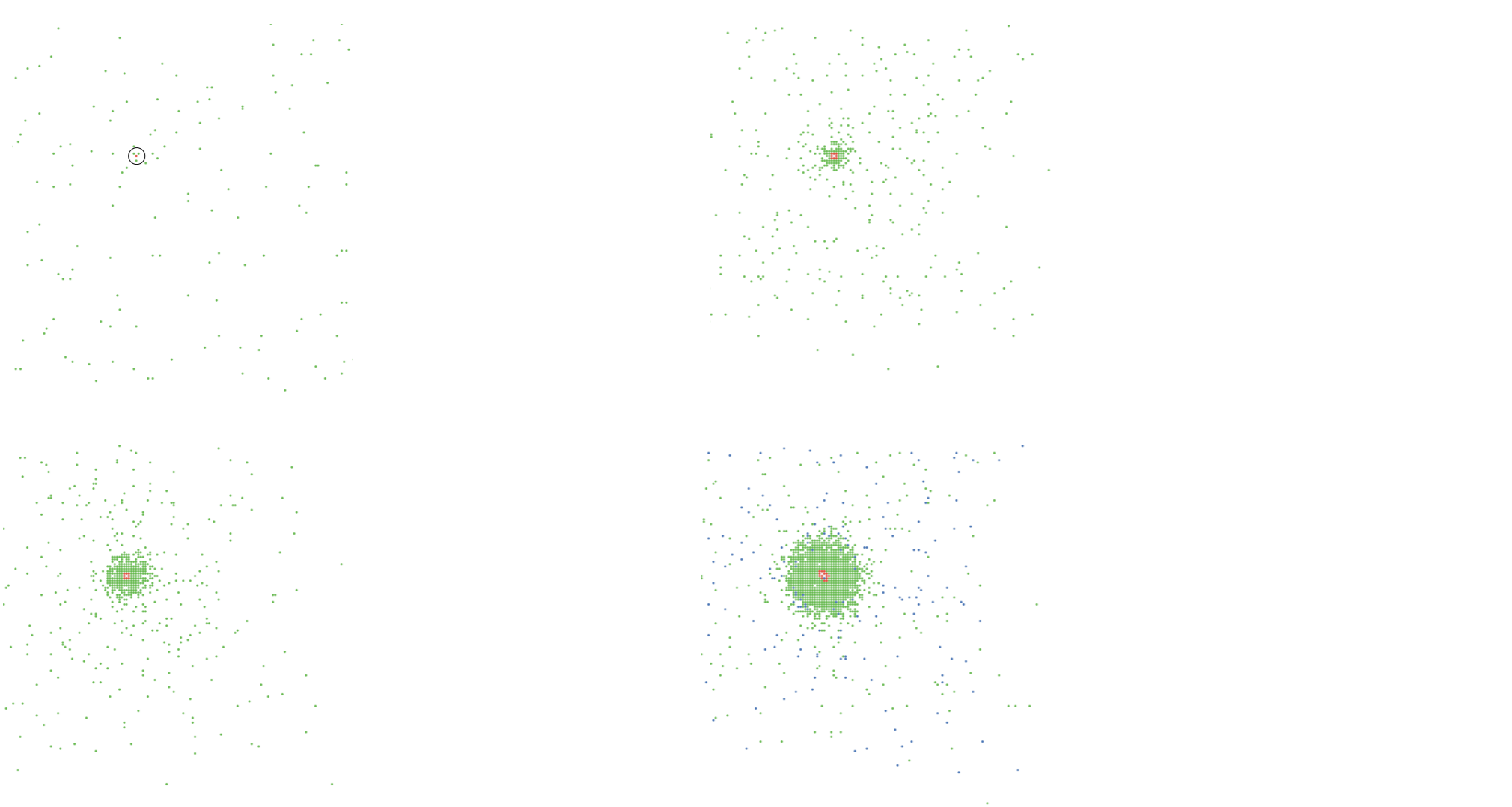


Figure: Agent-based model of granuloma formation in Netlogo [3]; uninfected macrophages are coloured green, infected macrophages are coloured red and T-cells are coloured blue

Swarm Robotic Systems

The similarity of between granuloma formation and swarm robotic systems [4]

Table: Properties of granuloma formation and swarm robots

Properties of swarm robotics	Properties of Granuloma Formation
Large number of robots	Large number of cells
Few homogeneous groups of robots	Few homogeneous cells
Relatively incapable or inefficient robots	Each cell needs each other to perform the desired task
Robots with local sensing	Chemokines, cytokines

- In granuloma formation, macrophages form a 'wall' around the chronically infected macrophages with the objective of separating the infected and uninfected cells.
- This properties can be instantiated in swarm robotic systems that have failure

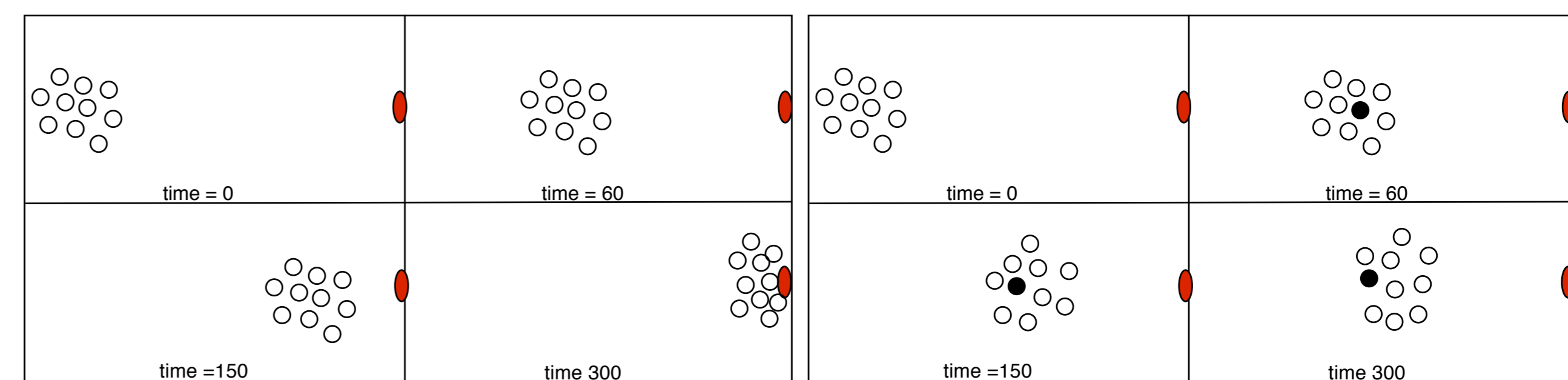


Figure: Instantiating the ideas of granuloma formation to swarm robots

Swarm Taxis and Self-Healing

Scenario:

- Swarm of robots aggregate towards a beacon
- Assuming that there is an energy failure in the systems, such that one, or more, of the robots ceases to move
- Failing robots will now act as an 'anchor point' for the swarm and potentially lead to swarm stagnation
- Isolate and the failing robot and starts to share energy (self-healing)



(a) Without faulty robots

(b) With faulty robots

Figure: Possible issues in swarm taxis, the anchoring issue

Conclusion

Using a simplified model of granuloma formation, we are able to abstract the behaviour of cells during the development of a granuloma, specifically, the trafficking of uninfected macrophages and T-cells to the site of infection. This model has been used to derive a distributed algorithm that mimics the properties of granuloma formation and aggregate robots to initiate self-repair in the context of a swarm robotic system.

Acknowledgement

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