



Emergent Teamwork

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Cognitive Animation Workshop • June 4-5, 2008 • Yosemite



This talk

- Whirlwind tour of collective behavior in nature
- Some earlier simulation models
- Recent work on agent-based “collective construction”

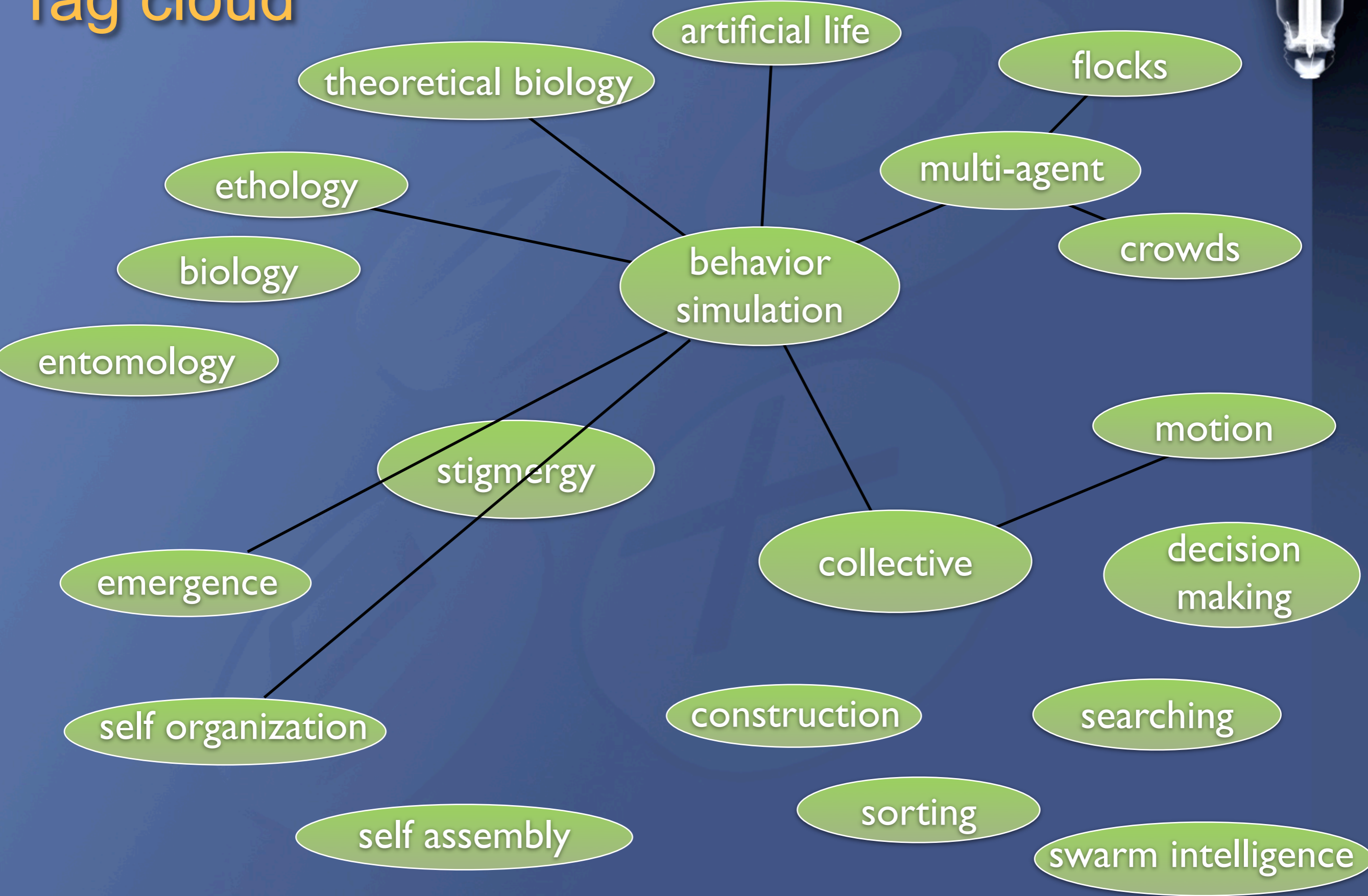


Tag cloud



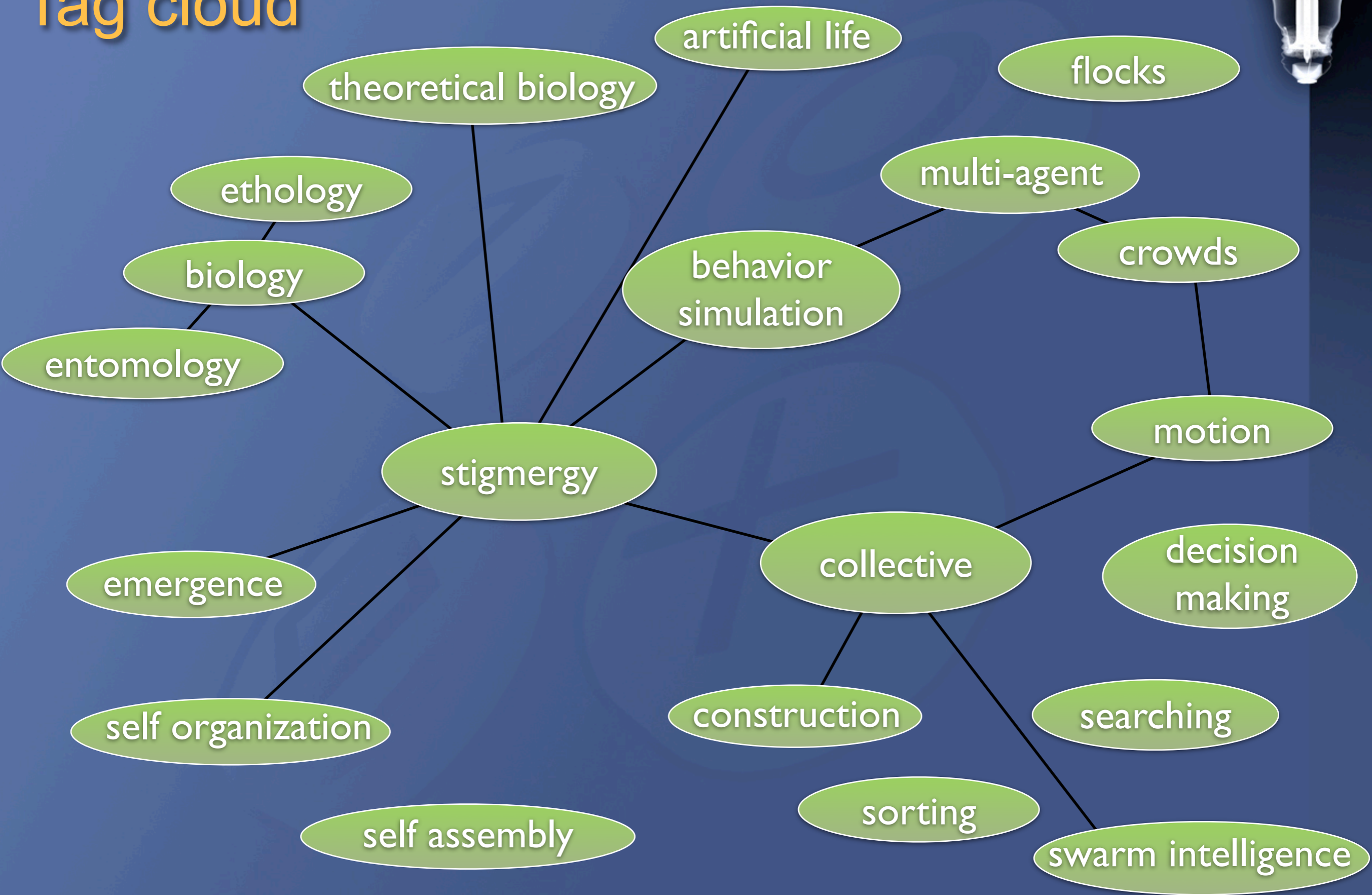


Tag cloud





Tag cloud





Stigmergy

- Communication through the environment
 - often with pheromones
 - physical marks or structures
 - no abstract communication required
- Coined in 1959 to describe construction by termites
 - by the French biologist Pierre-Paul Grassé
 - from Greek words *stigma* (sign) and *ergon* (action)



© Bricklaying by MC MasterChef via Flickr

Humans building a brick wall:

- obvious where to place next brick
- add more people to build faster
- typically coordinated with language



History of a long delayed project

- My interest in stigmergy goes back to talk by Eric Bonabeau at the Santa Fe Institute around 1998
- I first wrote a description of this specific project in 2005, but other things interfered...





Collective, cooperative behaviors in nature



Ant trail

Matabele army ants raiding termite nest

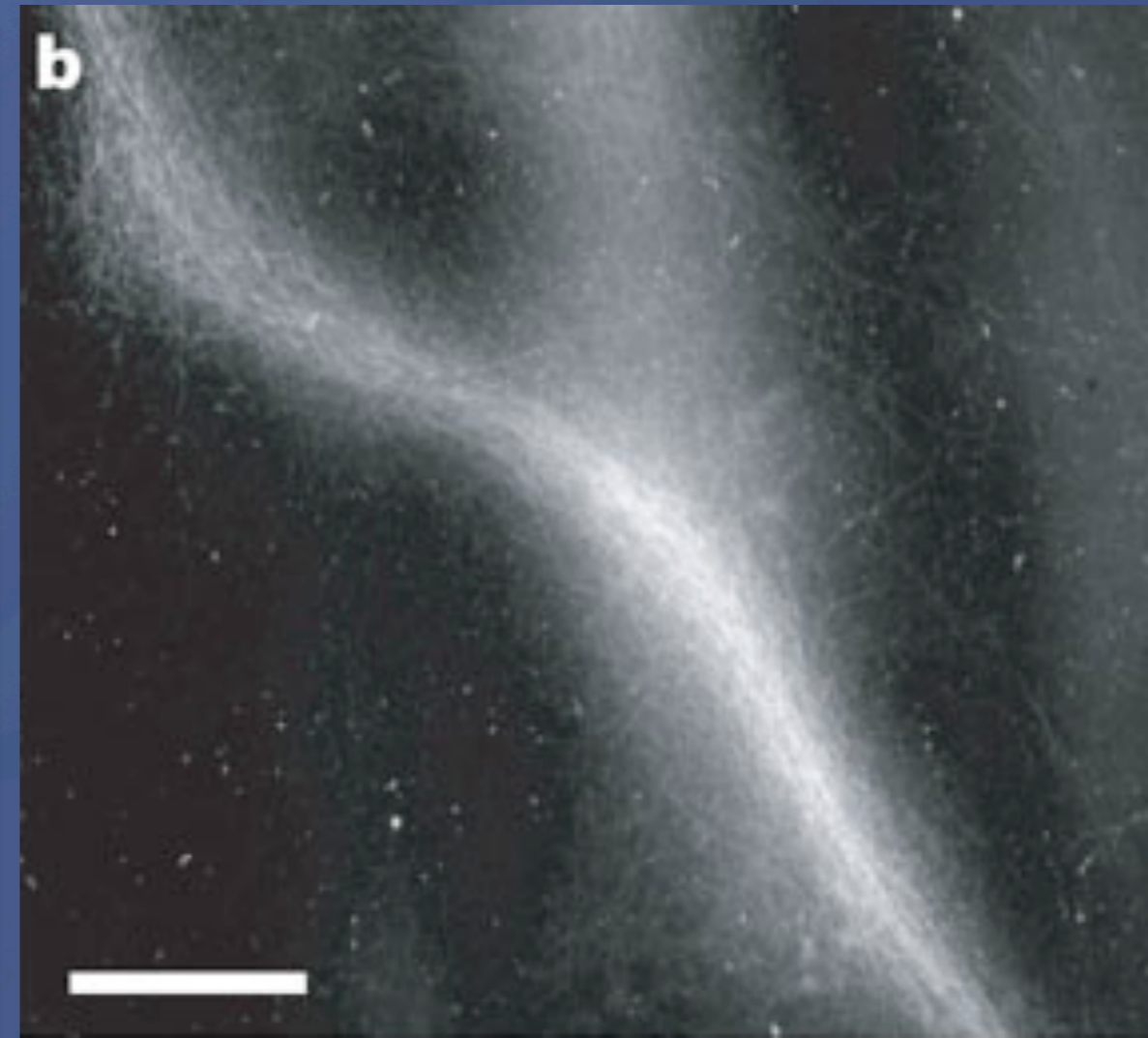
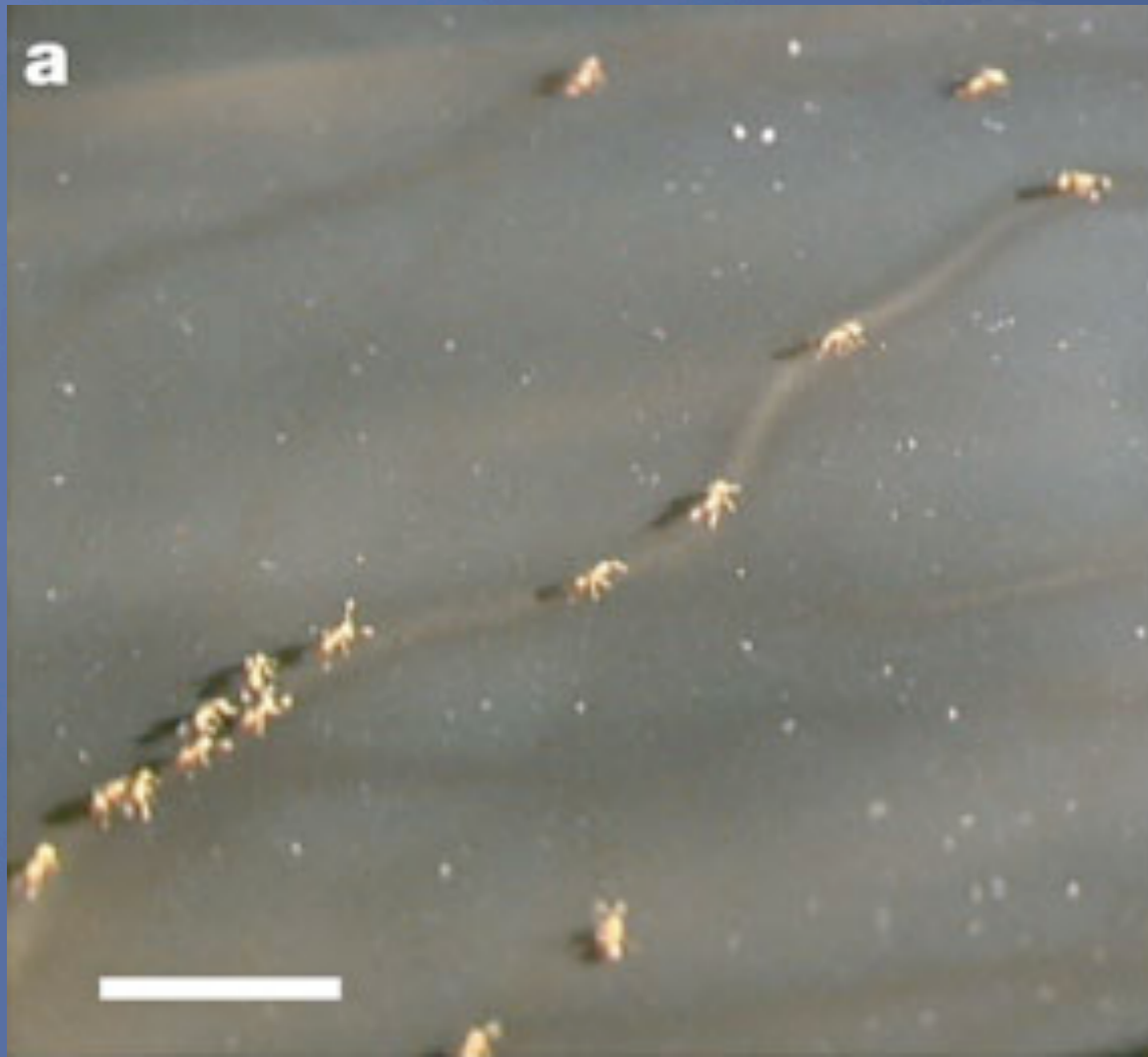


© Bruce G. Marcot

© Dr. Bruce G. Marcot, Ecology Picture of the Week, 11-17 August 2003



Ant foraging and pheromone trails



Jackson, Holcombe and Ratnieks, Nature 432 (16 December 2004)

Pheromone trail networks of Pharaoh's ants on a smoked glass surface



Scott Powell and Nigel Franks, in Animal Behaviour, 2007

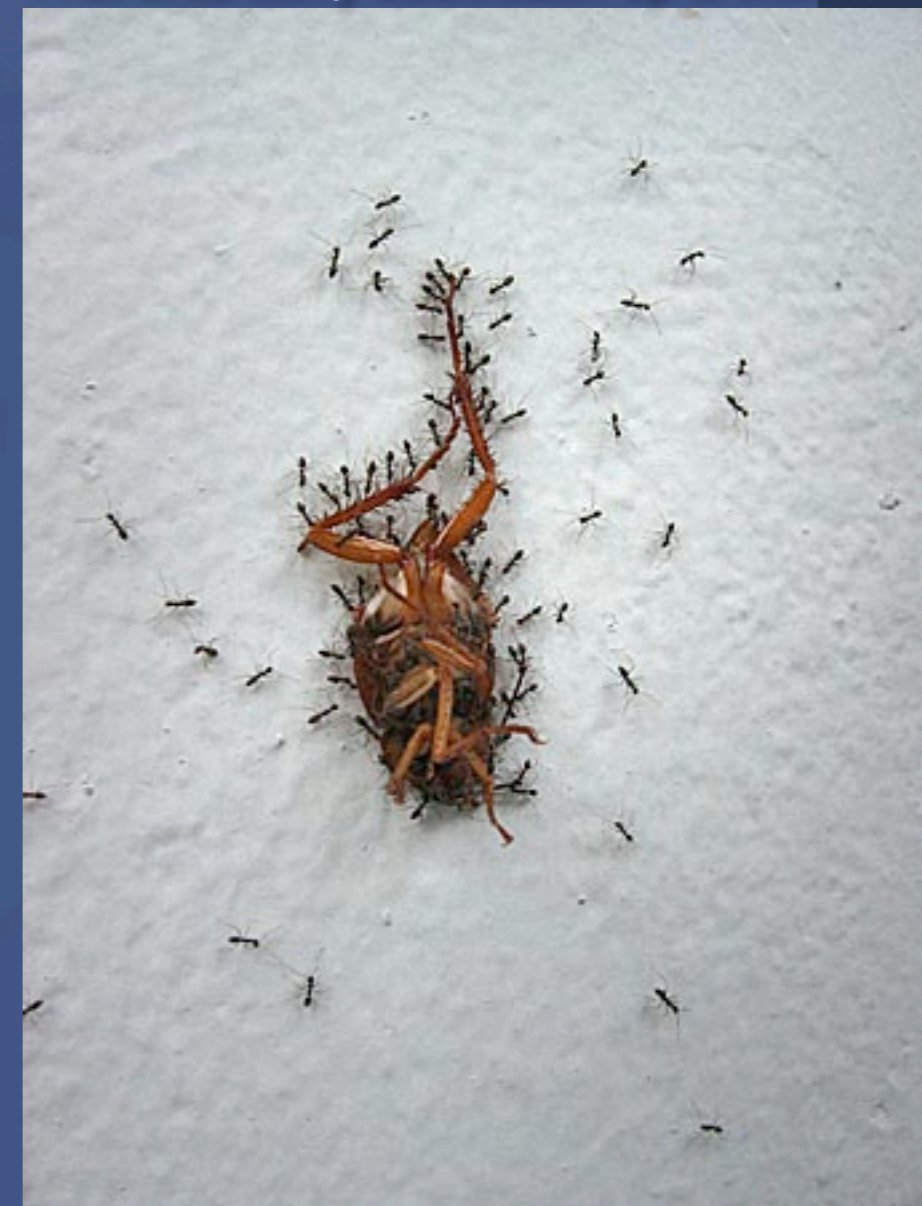
Army ants covering “potholes” with their own bodies



Ant teamwork: carrying large prey

- Porters:
 - Ants returning from forage
 - Carry prey larger than themselves
- Nigel Franks, 1986:
 - “Superefficient teams” -- nearly same speed as individual porters
 - Linear relation between ant and prey weight

Thai ants carry cockroach up a wall



Nik Daum (blog post Nov 2, 2005)



Ant teamwork: carrying large prey



Staub Family in Brazil (blog post July 19 2006)



Guzer (blog post Oct 27, 2007)



Ant porter team video



2007, kyledan2007, via YouTube



Paper wasp nest



*Paper wasp by Natasha Mhatre via Flickr
©2007, used with permission*

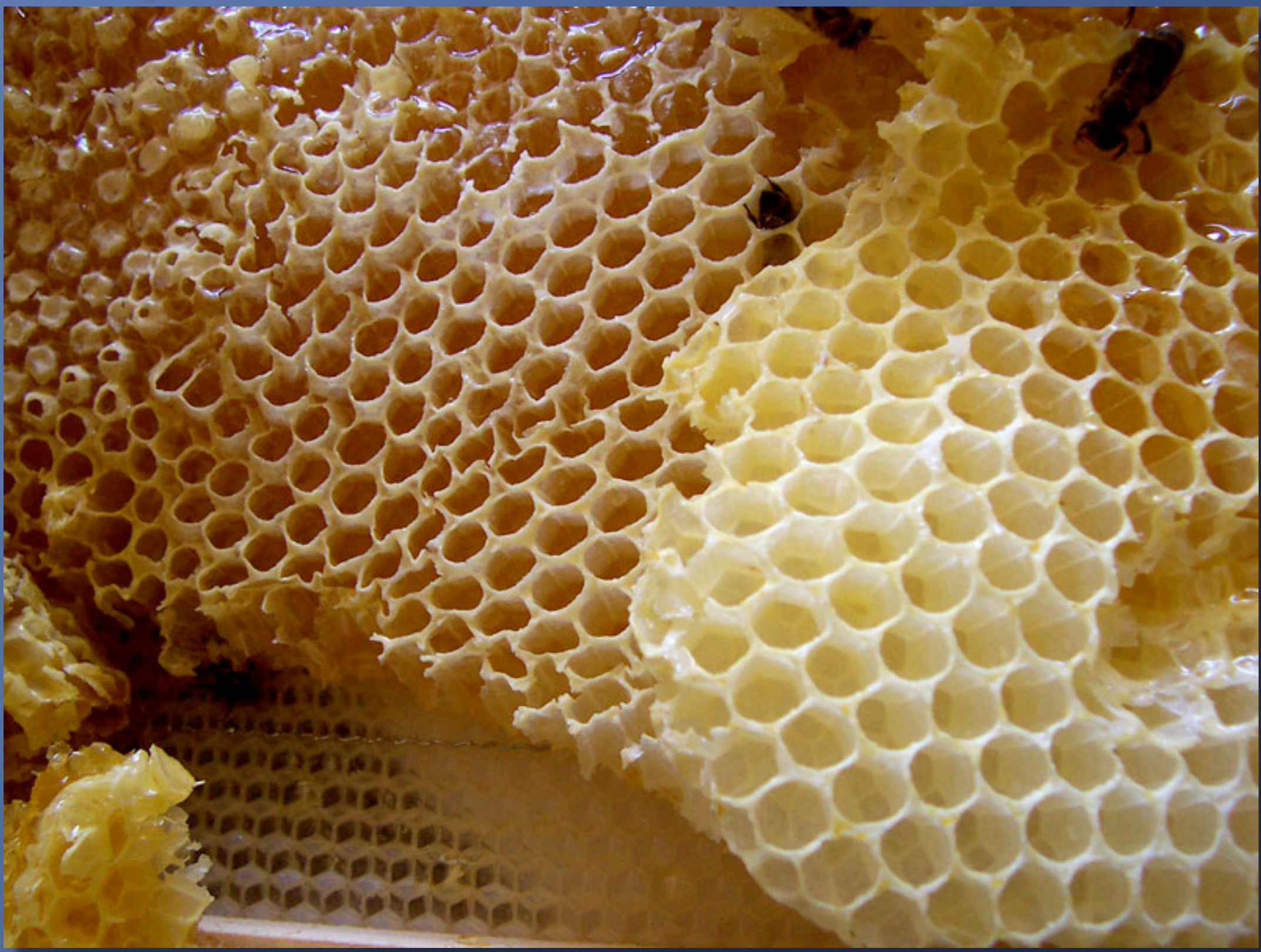
Potter wasp nest



*Potter wasp by Natasha Mhatre via Flickr
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Honeycomb



© 2007, Merdal, via Wikimedia Commons



Honey bee (*Apis mellifera carnica*) constructing comb



© 2007, Richard Bartz, via Wikimedia Commons



Collective decision making in honeybees

- Honeybee colonies split when they get too large
- Scouts identify potential locations for new hive
- Perform waggle dance to advocate their favorite
- Other scouts check out nominated locations
- Until a quorum of ~15 bees appear at one location
- They return to the bivouac to announce the new hive site has been selected and the colony moves



JH Underground (blog post February 9, 2007)

Collective hunting in mammals: gray wolf pack



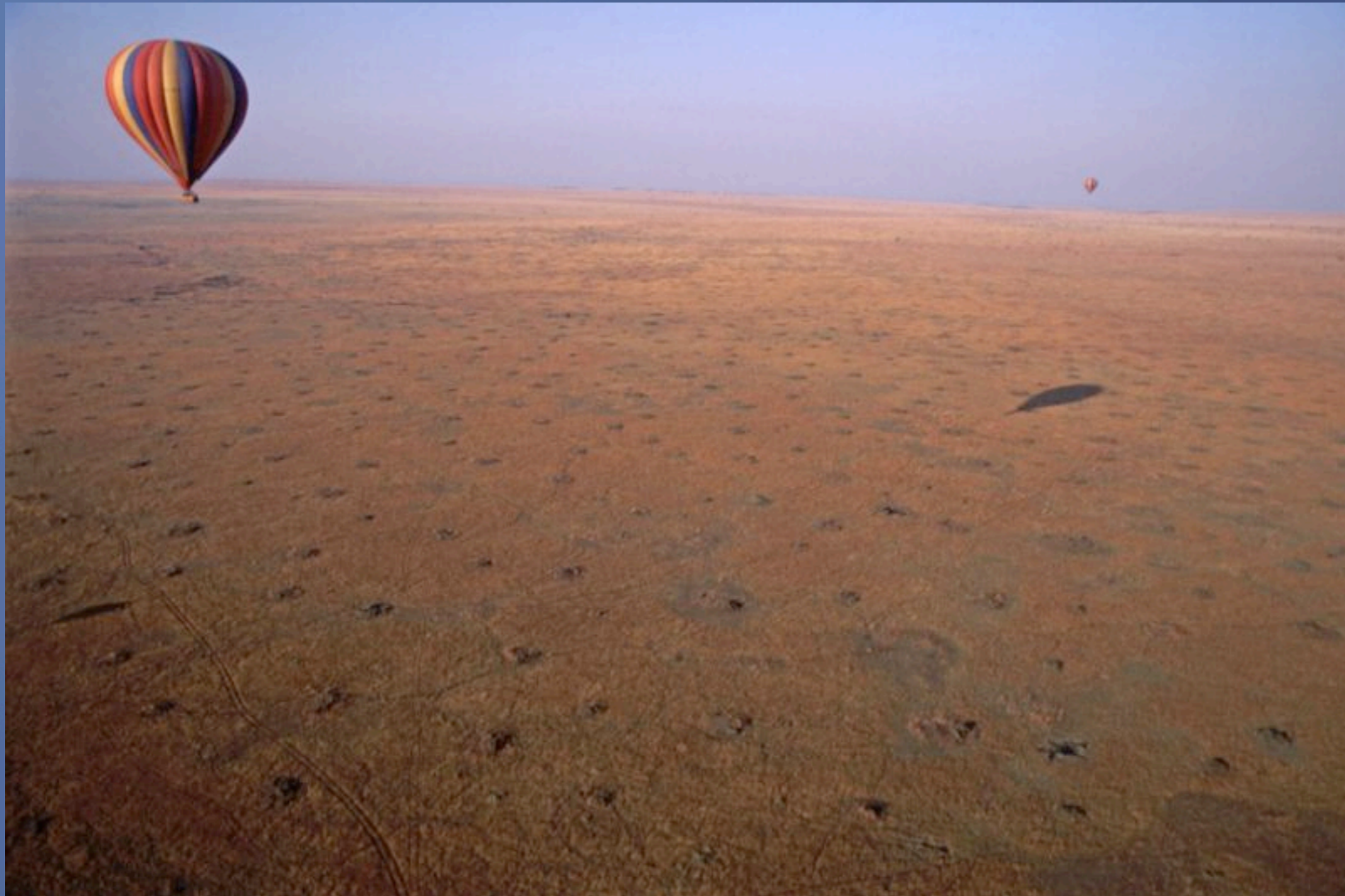
Termite mounds: size comparison



2005, Ray Norris, via Wikimedia Commons



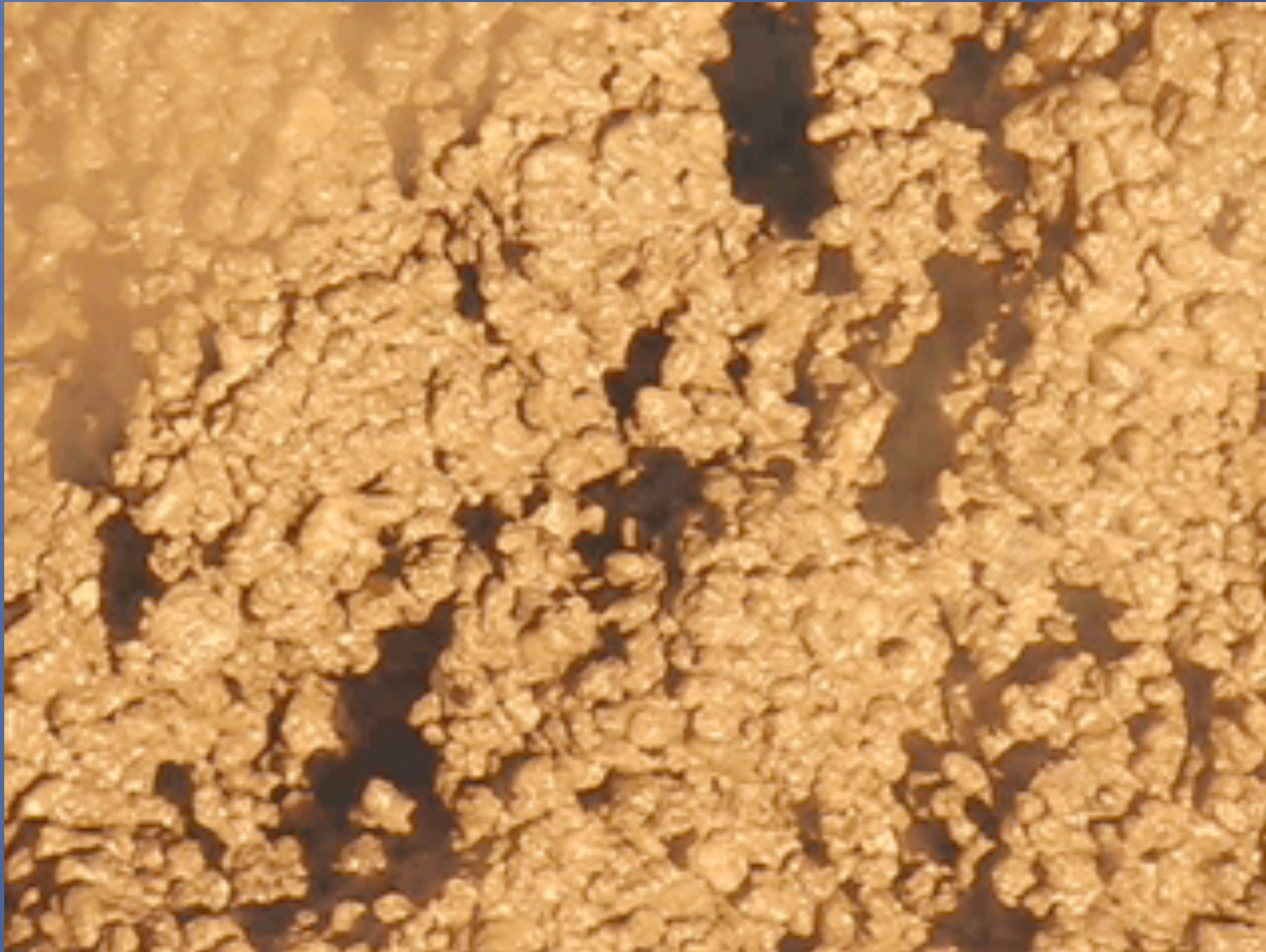
Termite mounds: abundance



1997, John Storr, via Wikimedia Commons



Termites repair mound with “spongy build”





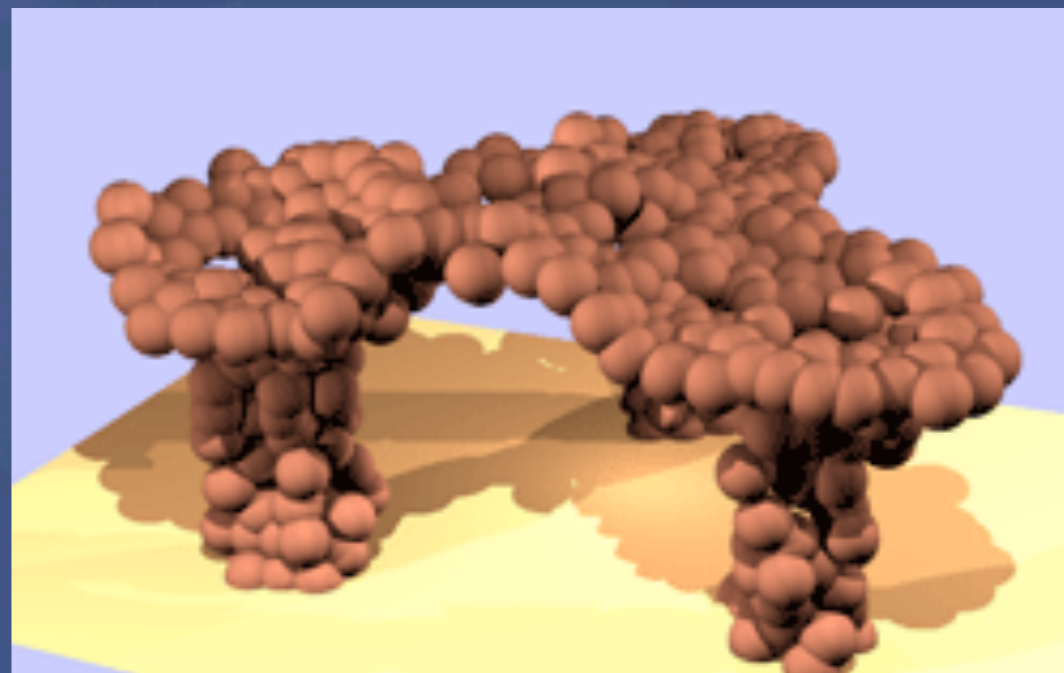
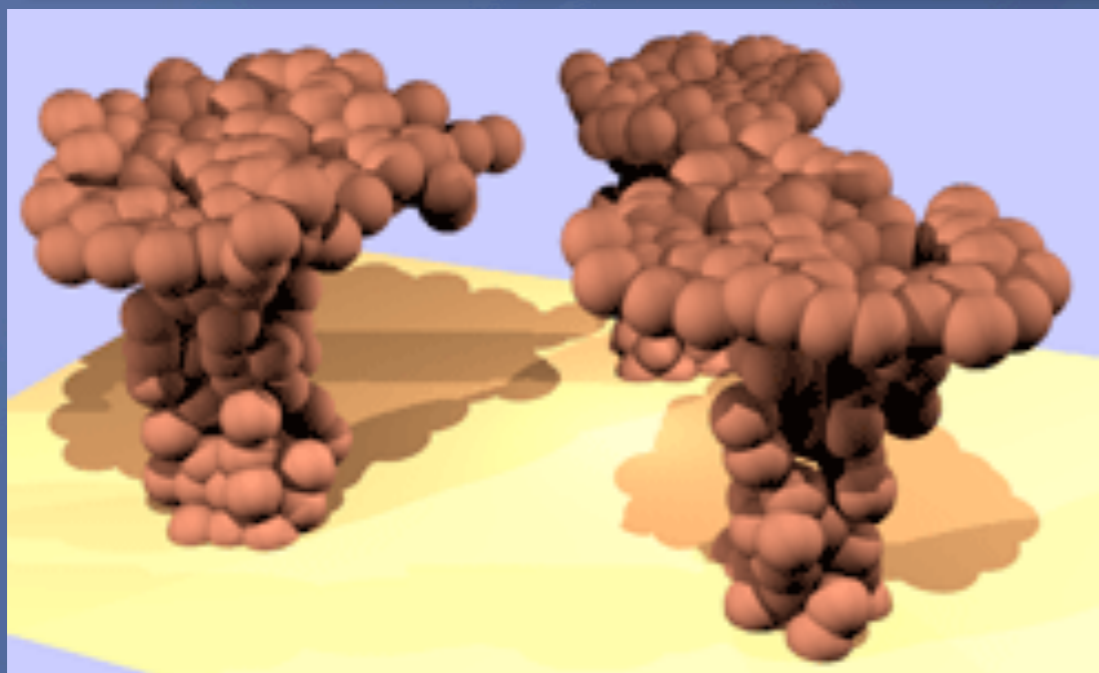
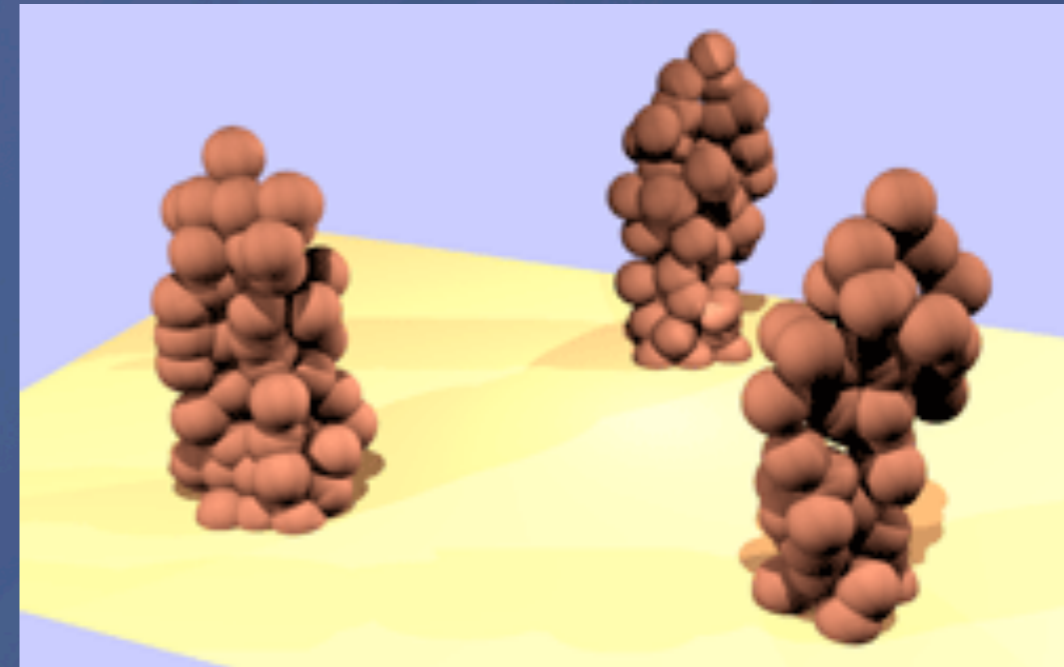
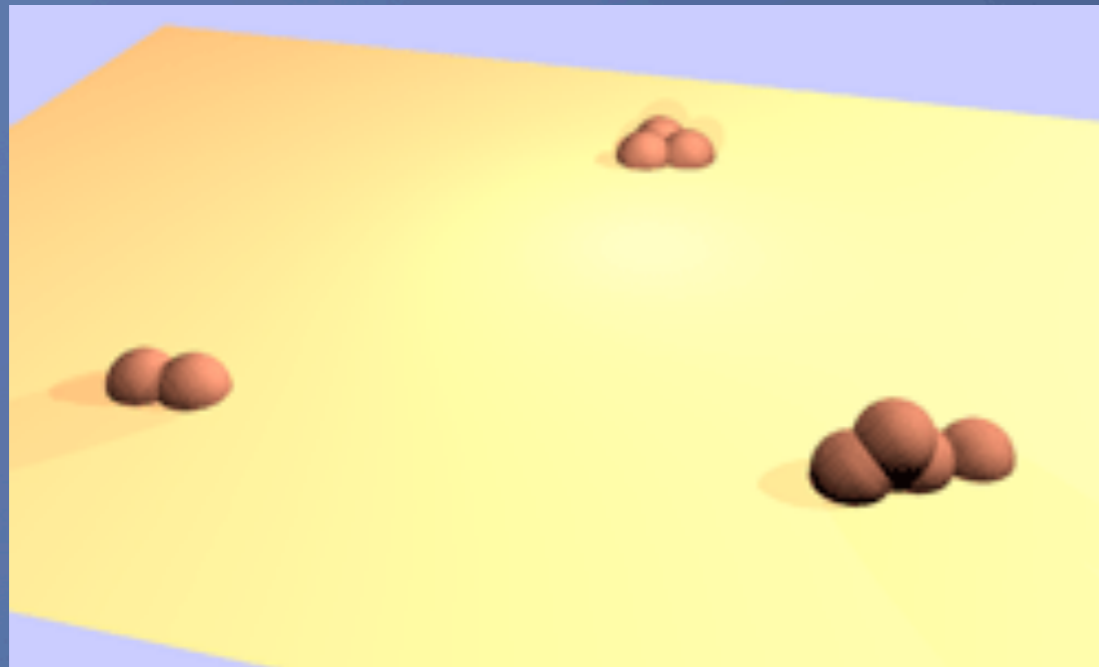
Termite “spongy build”



Scott Turner, SUNY Syracuse, used with permission



Termite stigmergic building: pillar construction and the roofed gallery



Scott Turner, SUNY Syracuse, used with permission



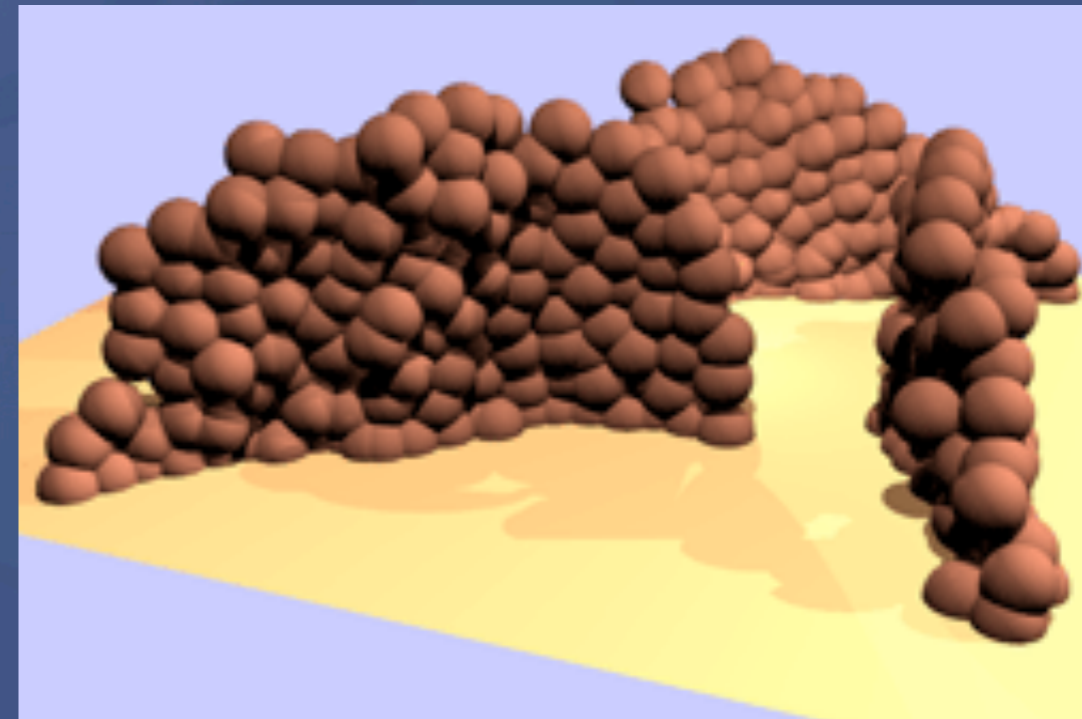
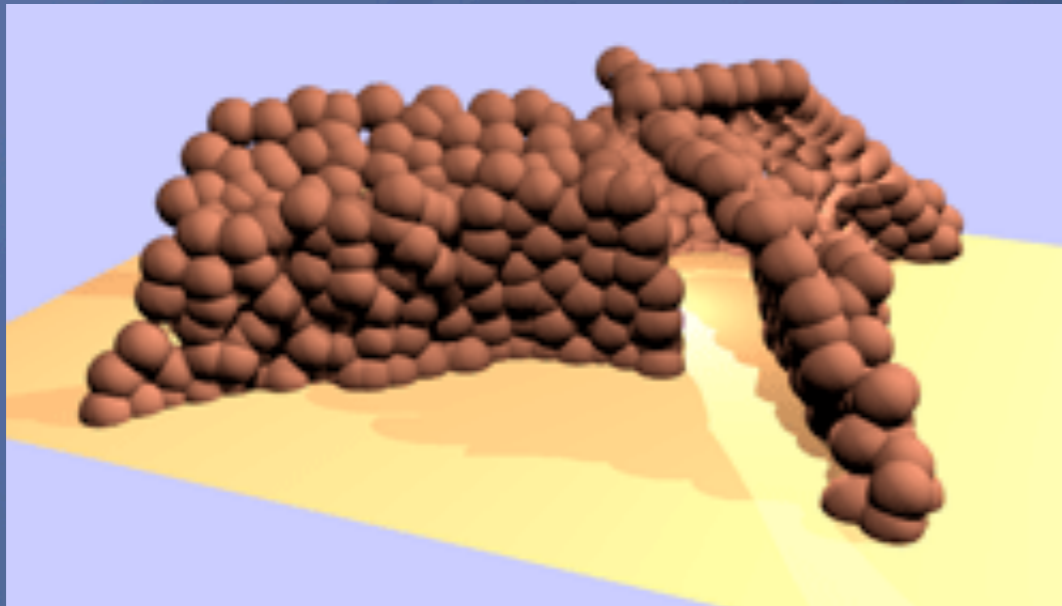
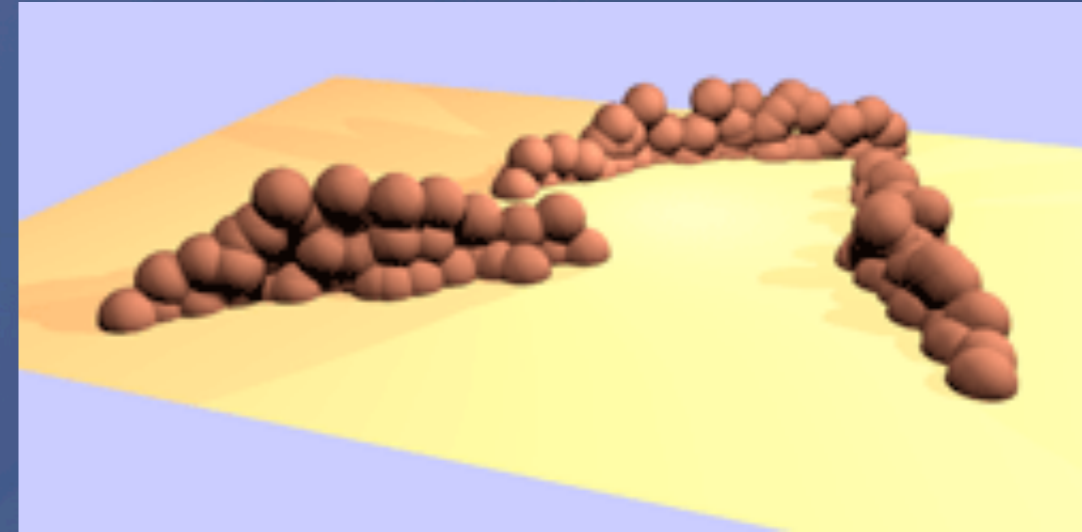
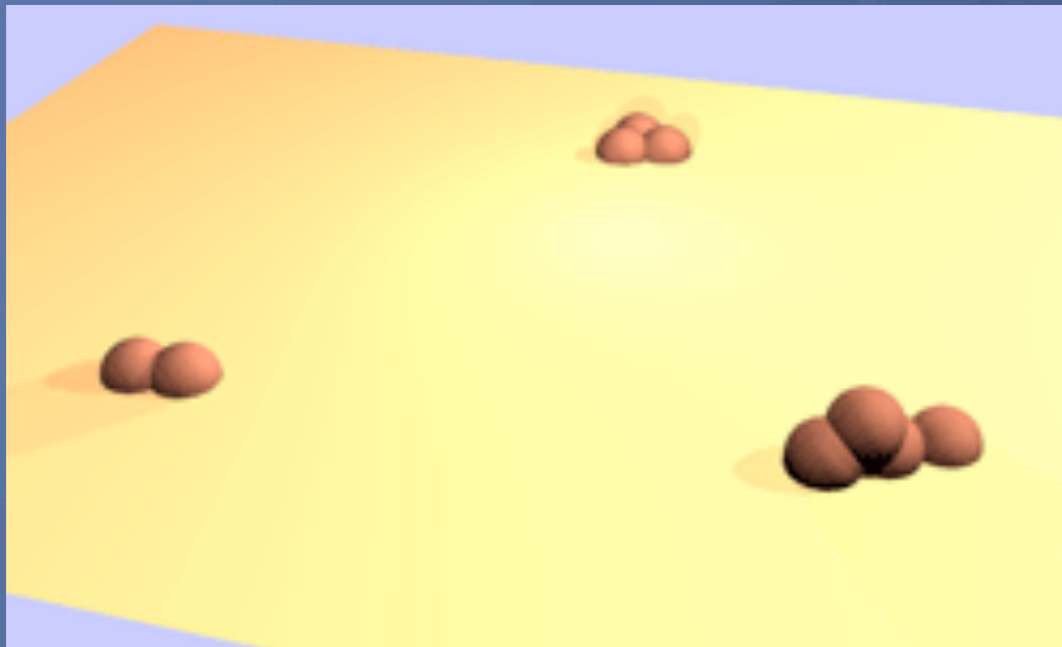
Termite pillar placement



Scott Turner, SUNY Syracuse, used with permission



Termite stigmergic building: Wall construction and enclosure of space



Scott Turner, SUNY Syracuse, used with permission



Wall buiding in damaged tunnel



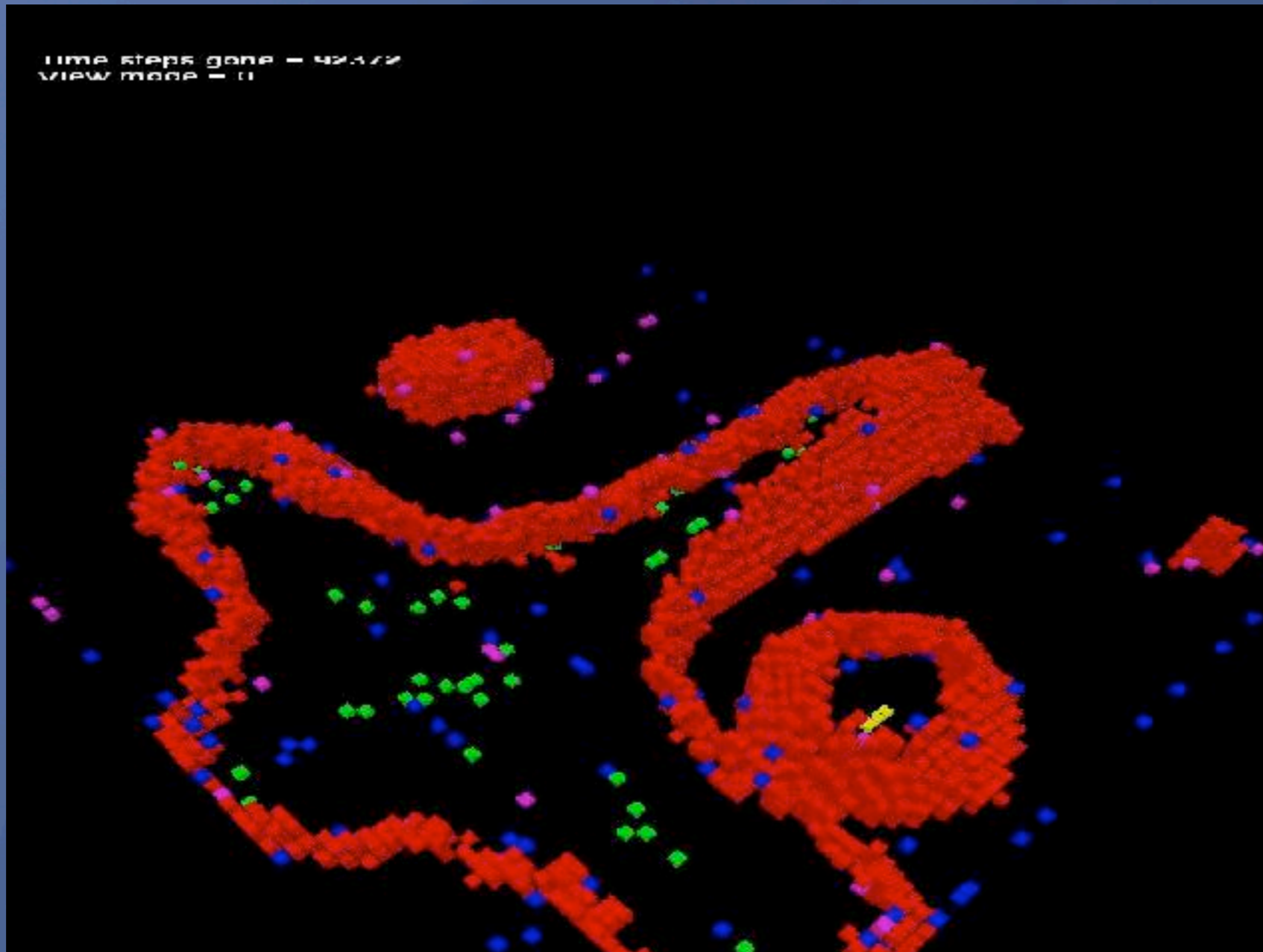
Scott Turner, SUNY Syracuse, used with permission



Simulation models



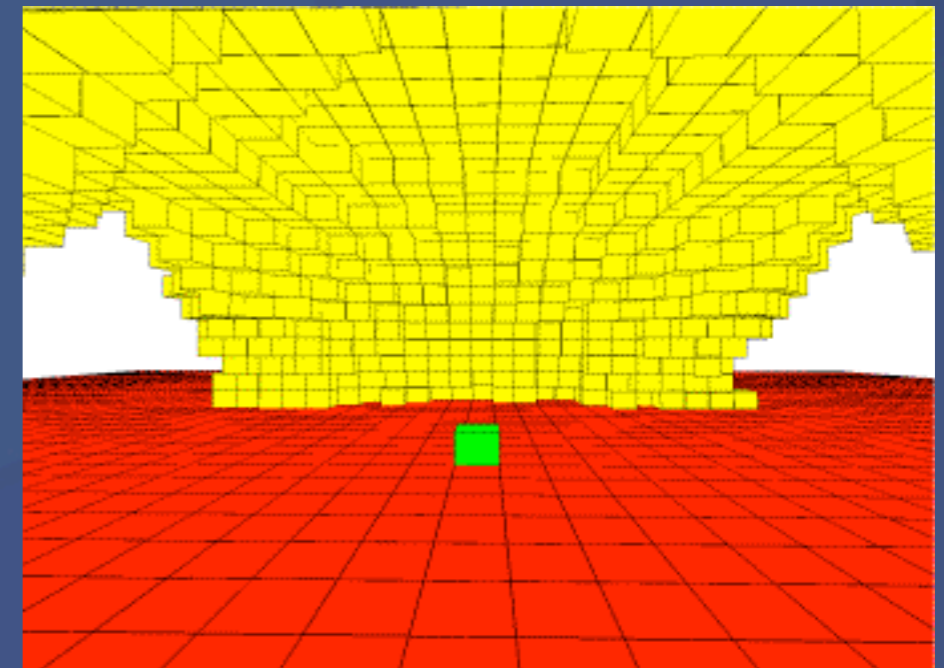
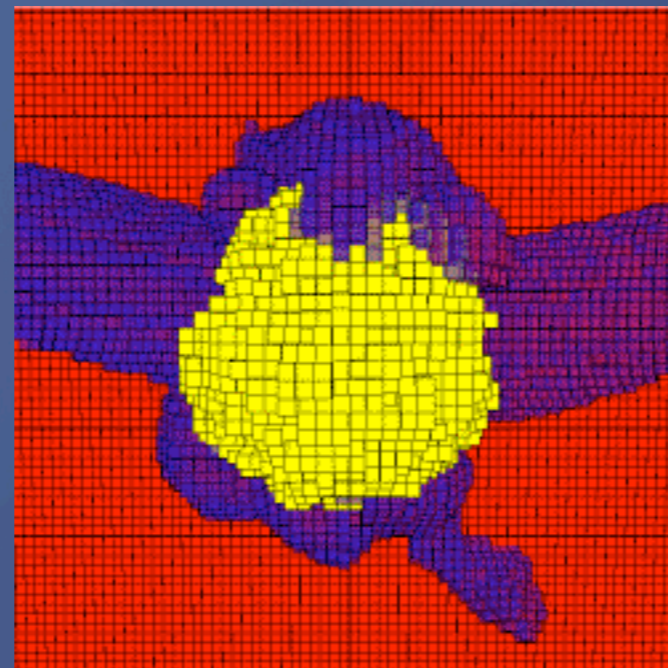
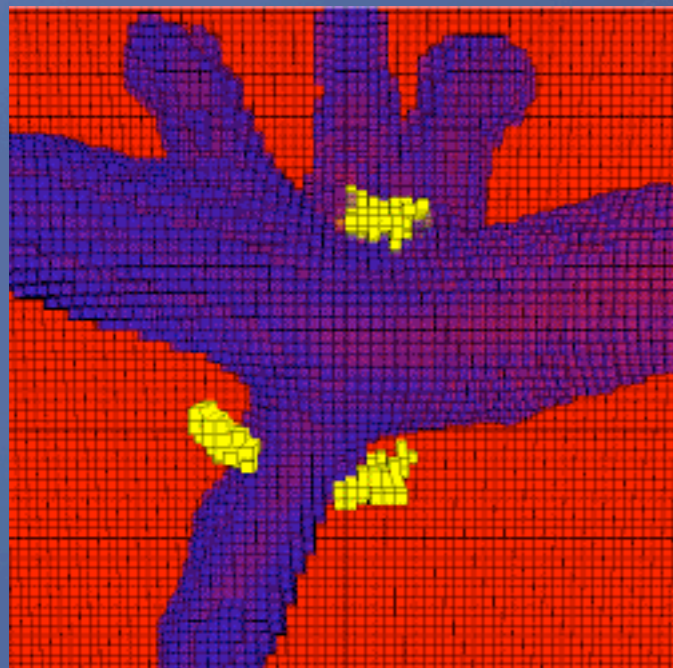
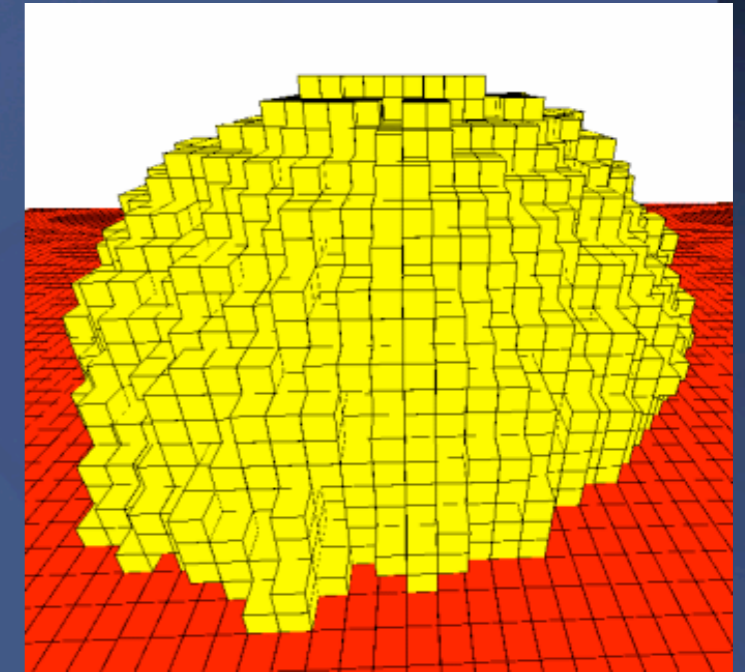
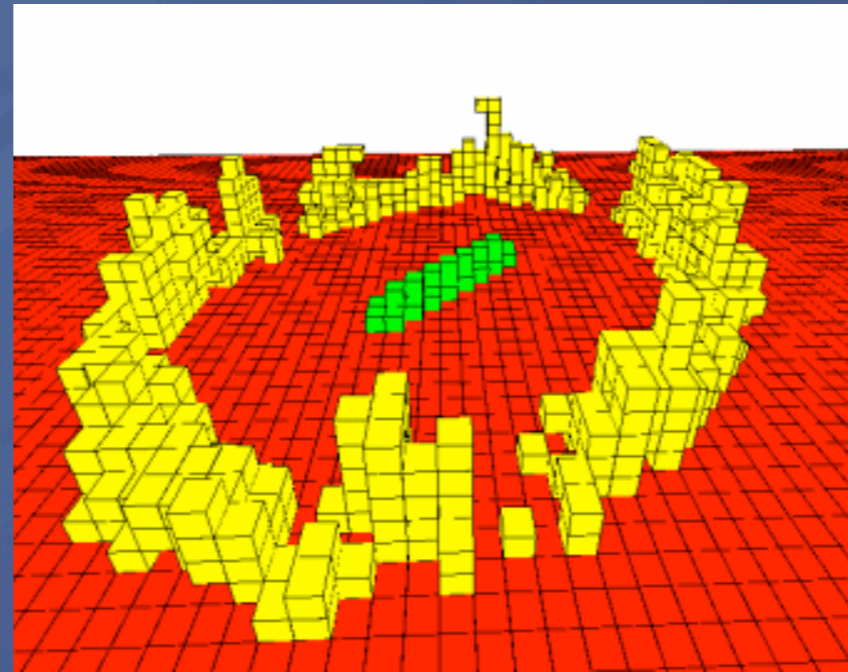
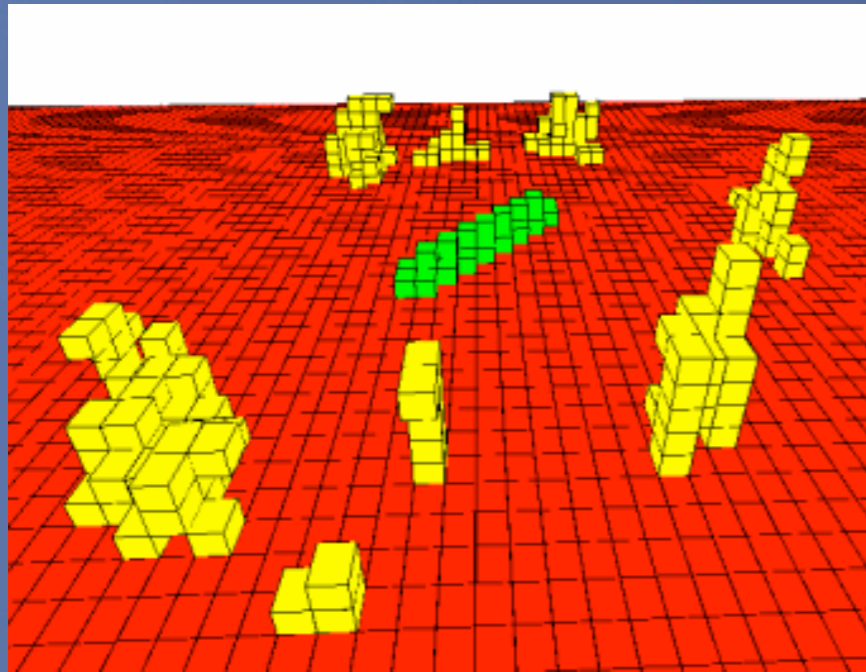
Termite model: discrete voxel space



Feltell, Li and Jensen, International Journal of Modelling Identification and Control, 2008



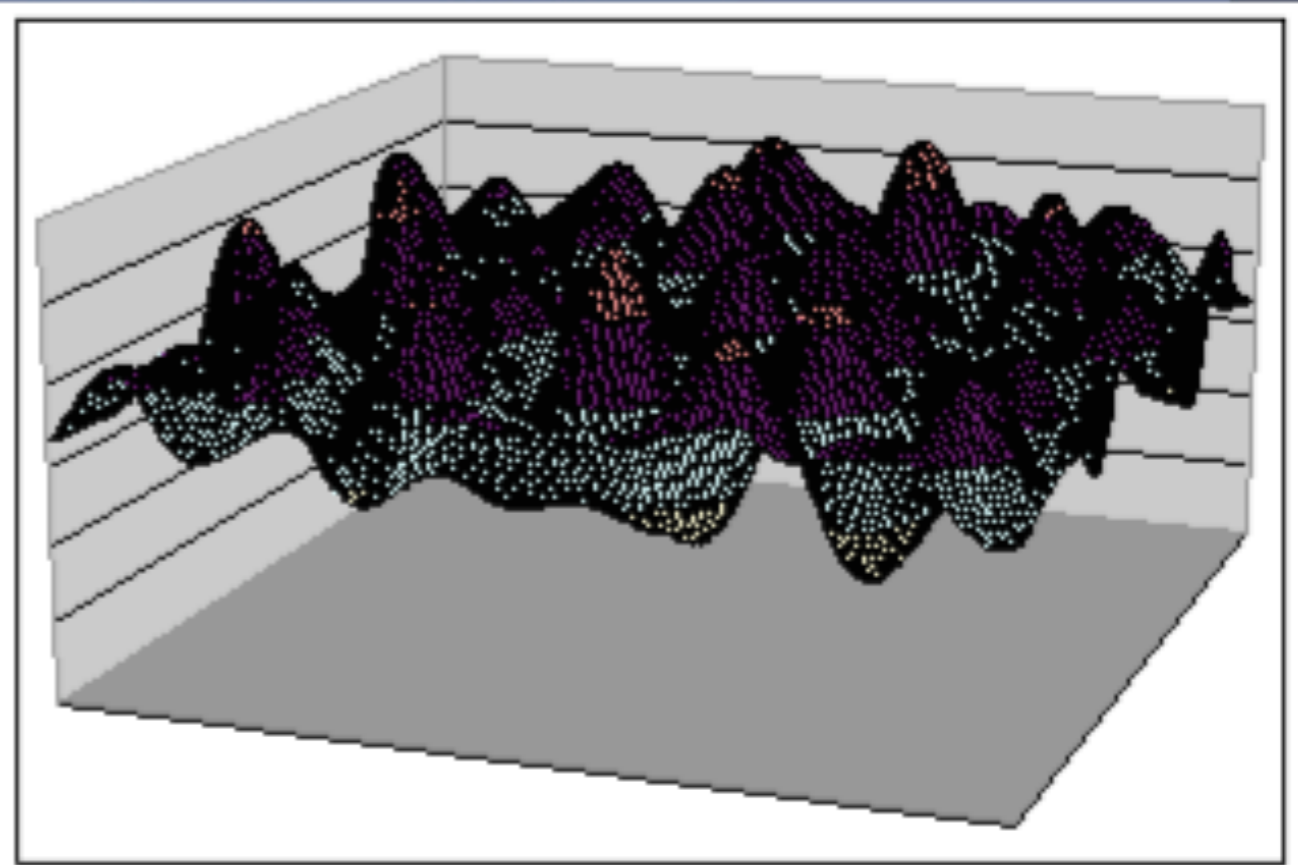
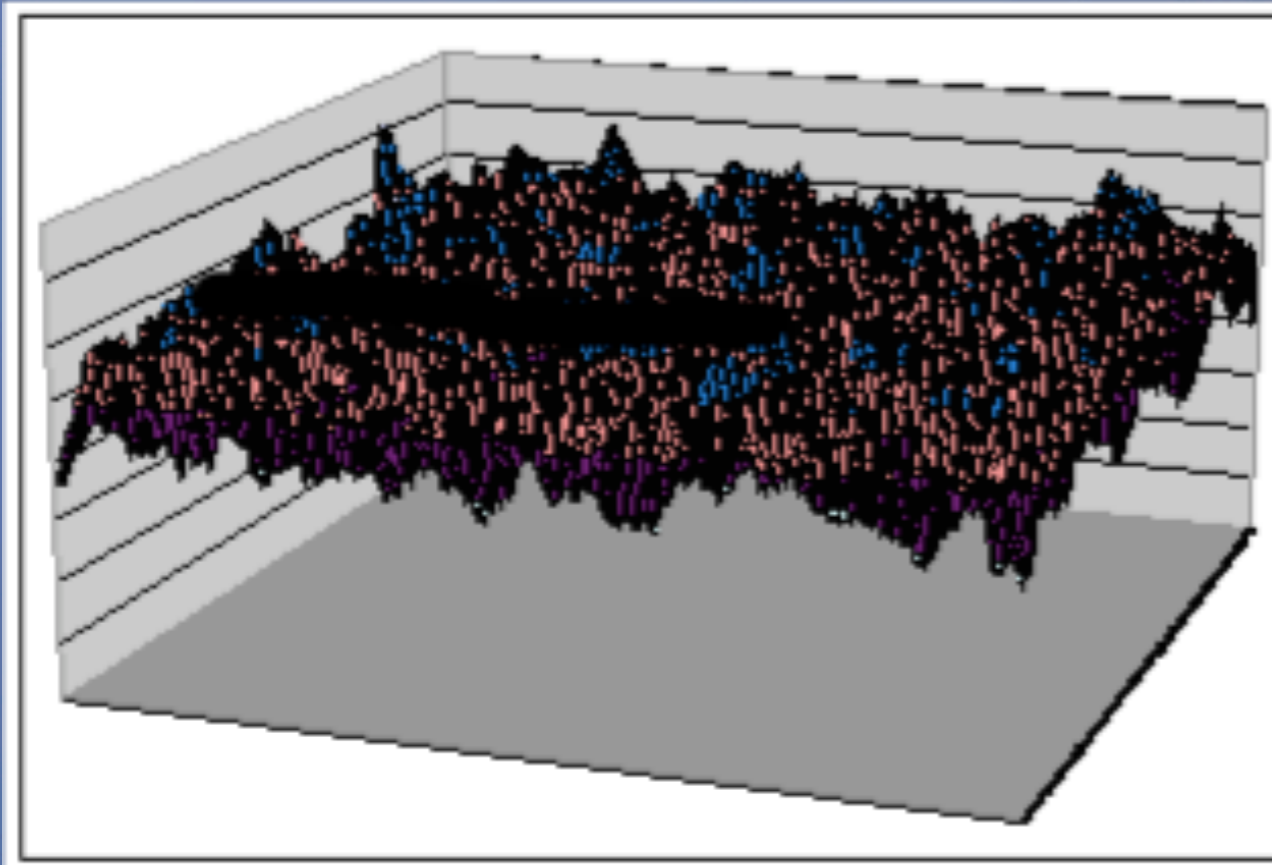
The role of logistic constraints in termite construction of chambers and tunnels



Ladley and Bullock, Journal of Theoretical Biology, 2005



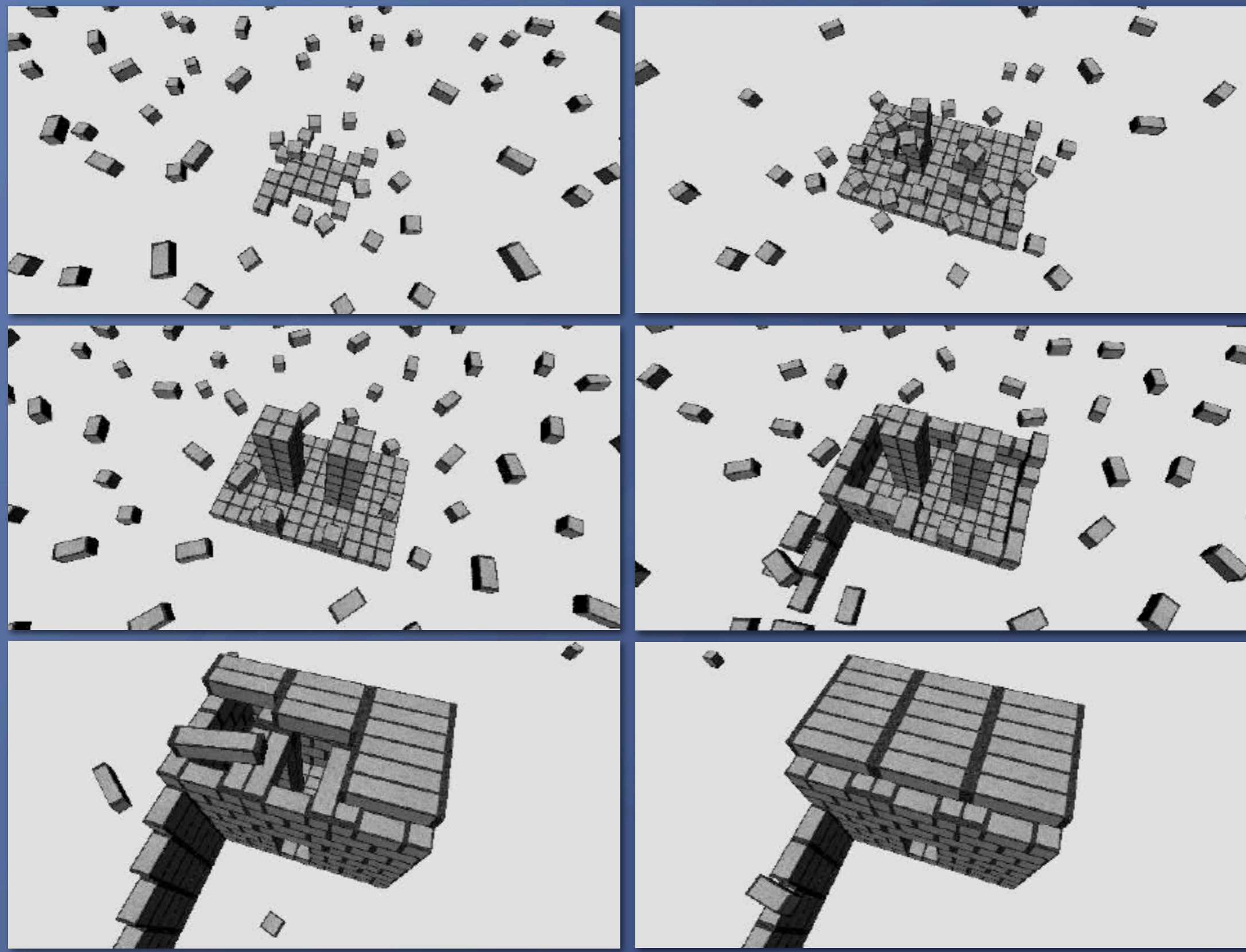
RD model of pillar placement



adapted from Bonabeau et al. 1998



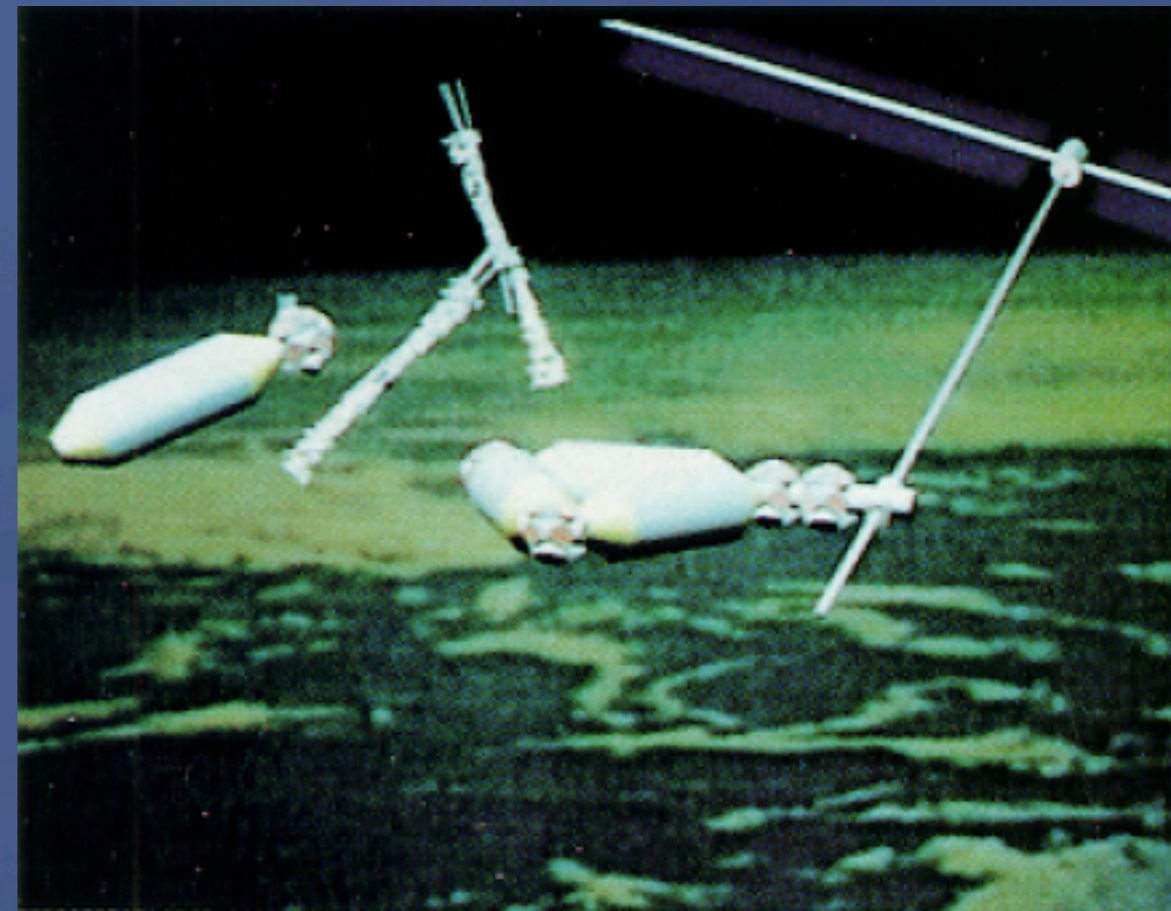
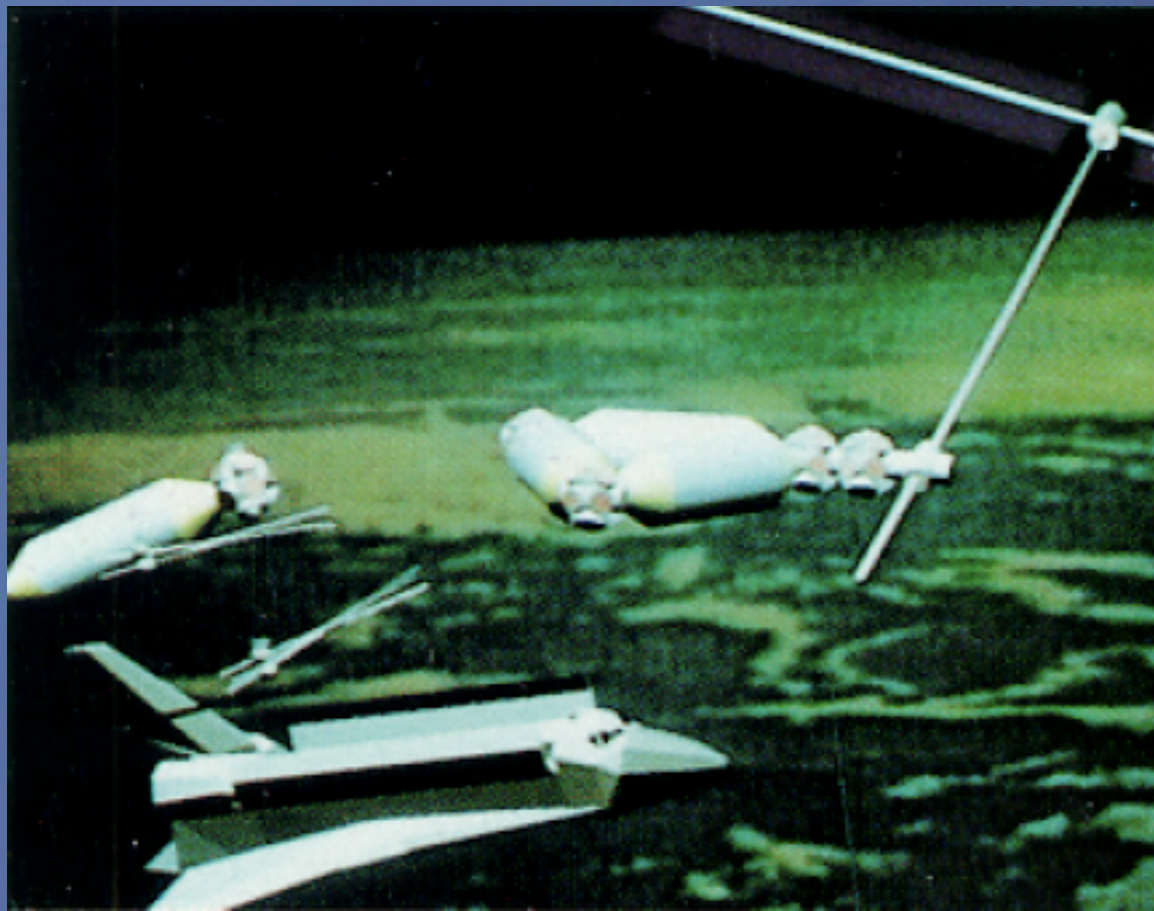
Stigmergic Self-Assembly of Prespecified Artificial Structures in a Constrained and Continuous Environment



Alexander Grushin and James Reggia, *Integrated Computer-Aided Engineering*, 2006



Computational techniques for the self assembly of large space structures (1987)



*Barr, Von Herzen, Barzel and Snyder, 8th Princeton/AIAA/SSI Conference, 1987
Barzel and Barr, SIGGRAPH, 1988*



Agent-based collective construction



Demo: simple construction with “bricks”

- Moving autonomous agents
- Passive bricks
- Gathering bricks together
- Piling bricks on top of other bricks
- Unaligned, irregular assemblies



Disk construction



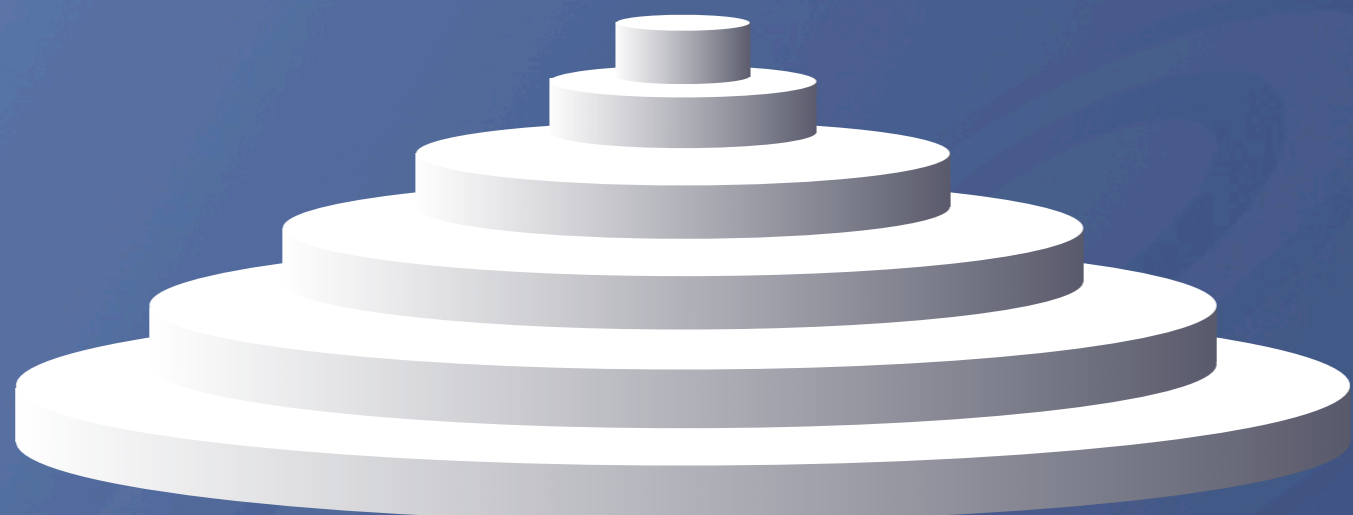
- Forage for bricks
- Return to construction site
- Deposit brick near edge of disk
- Repeat...



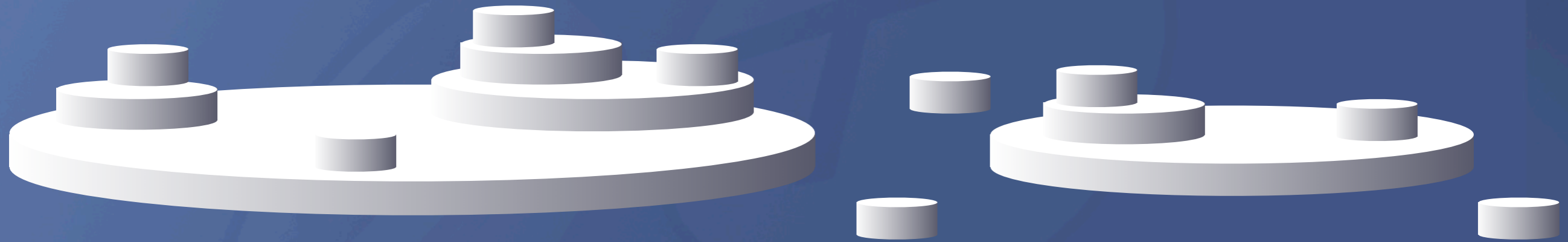
Heap construction



- Forage for bricks
- Return to edge of construction site
- Choose one of:
 - Deposit brick near edge of disk
 - Jump on top of disk, then deposit
- Repeat...



Fixed global construction target



Emergent construction target



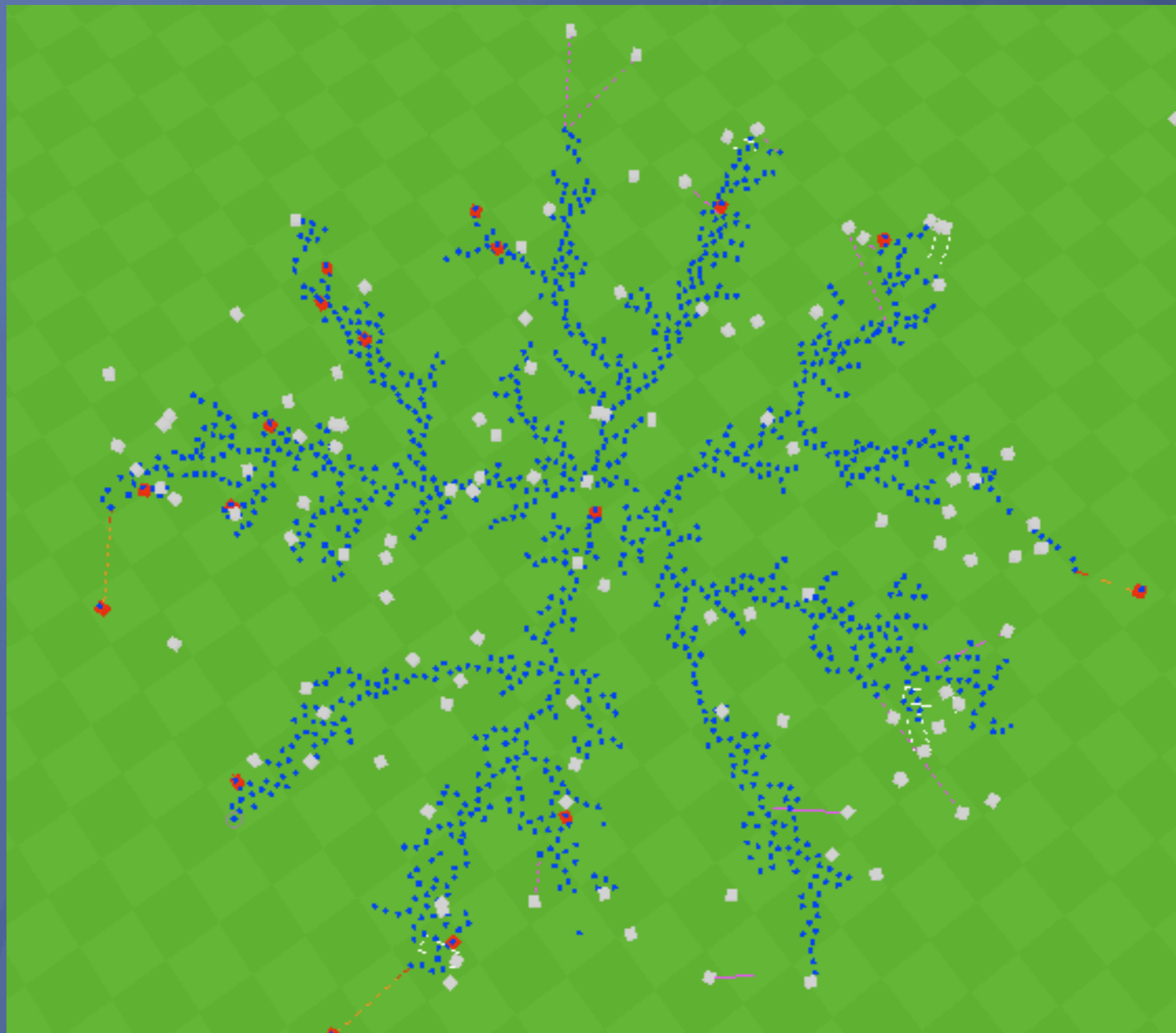
OpenSteer

- Steering behavior library, development tools, samples
- C++ implementation
- Open source (<http://opensteer.sourceforge.net/>)
- Provides: multi-agent framework, graphics, camera, clocks, spatial database, ...

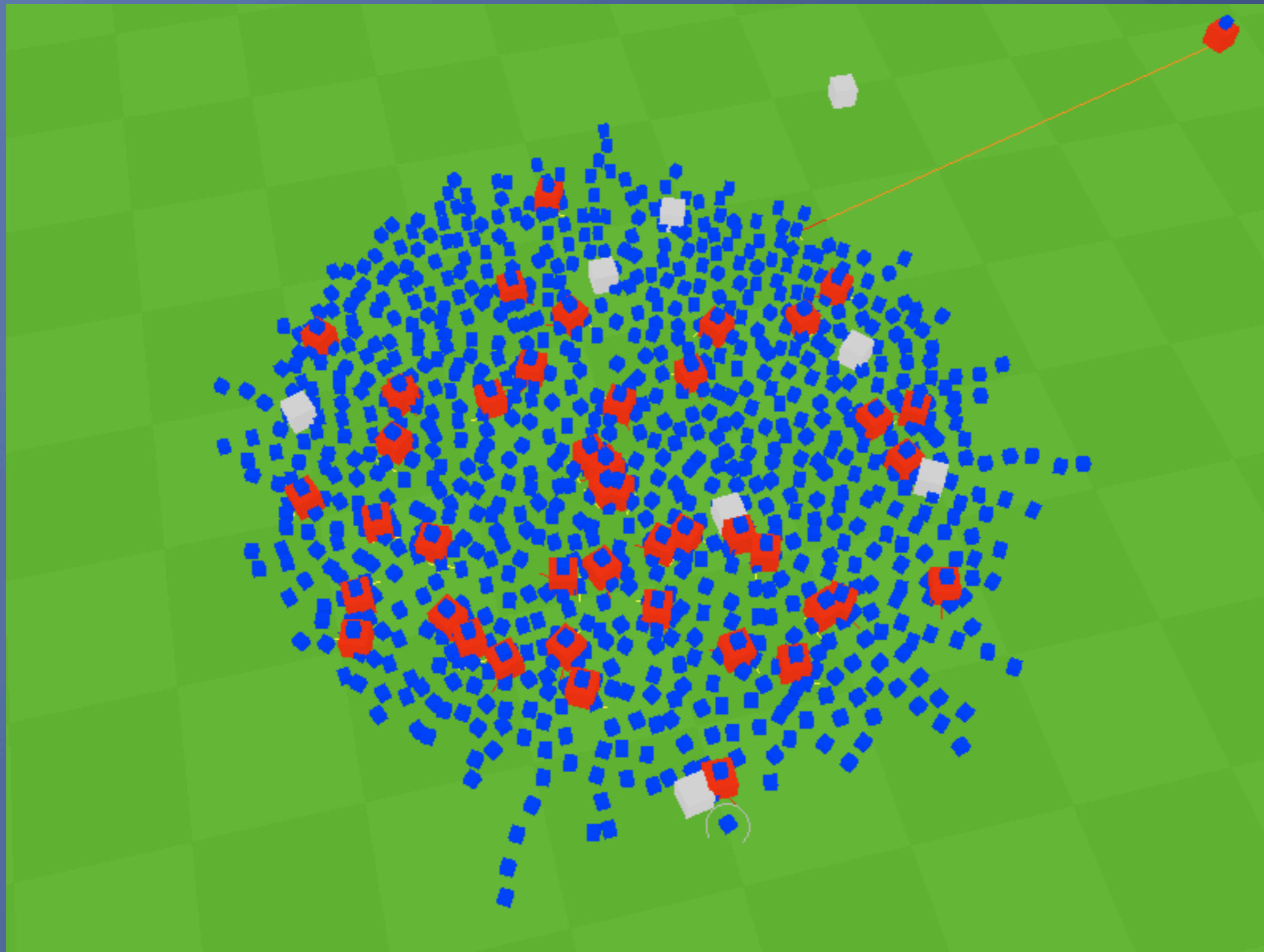




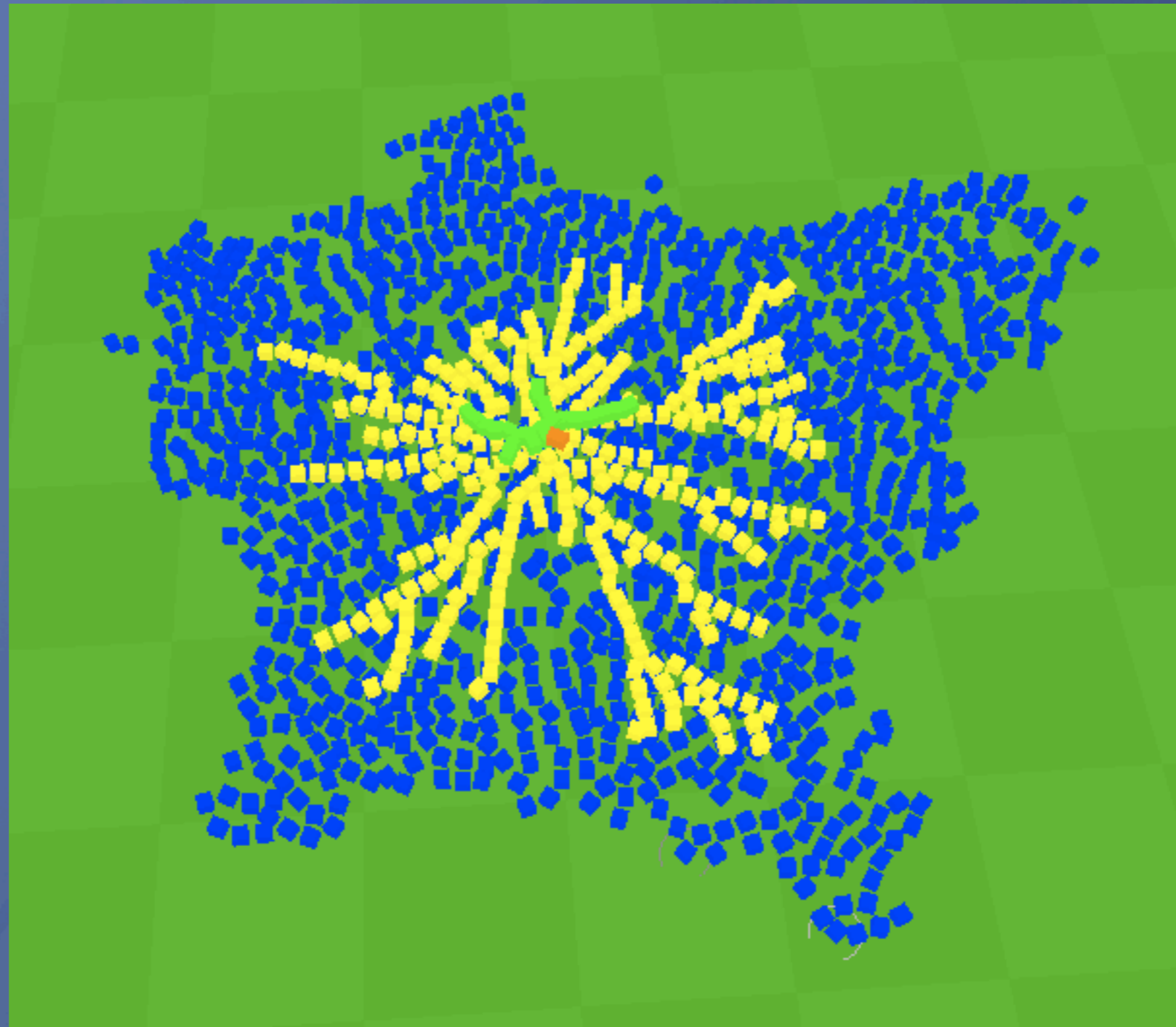
Demo



Near miss: behavioral DLA (diffusion limited aggregation)



Near miss: whirling dervishes, can't let go



First “heap” built with 1500 bricks with four layers