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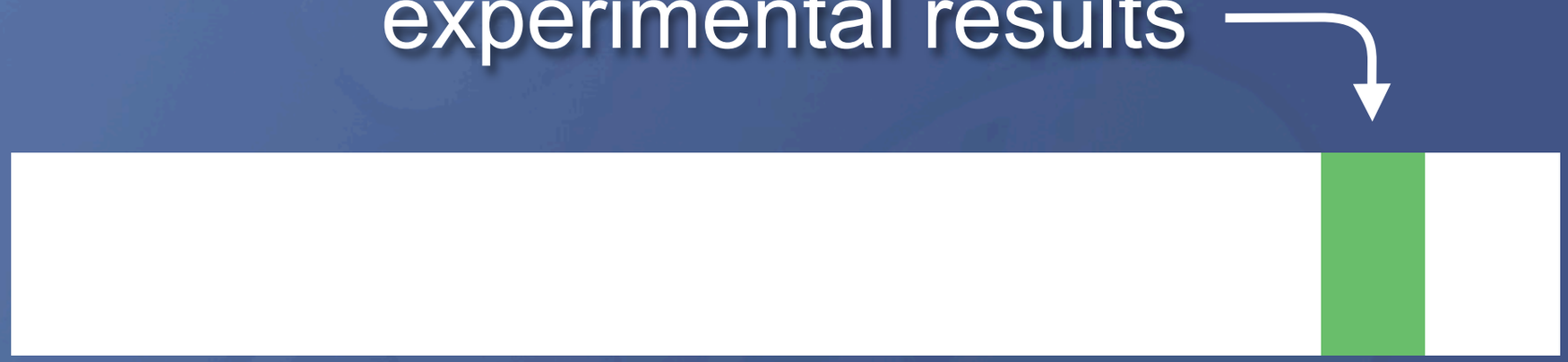
Crowds and Emergent Teamwork

Craig Reynolds

presented at CASA
June 2, 2010

Structure of this talk



Topics in this talk

- Steering behaviors
- Flocks and crowds
- “Non trudging crowds”
- Collective construction

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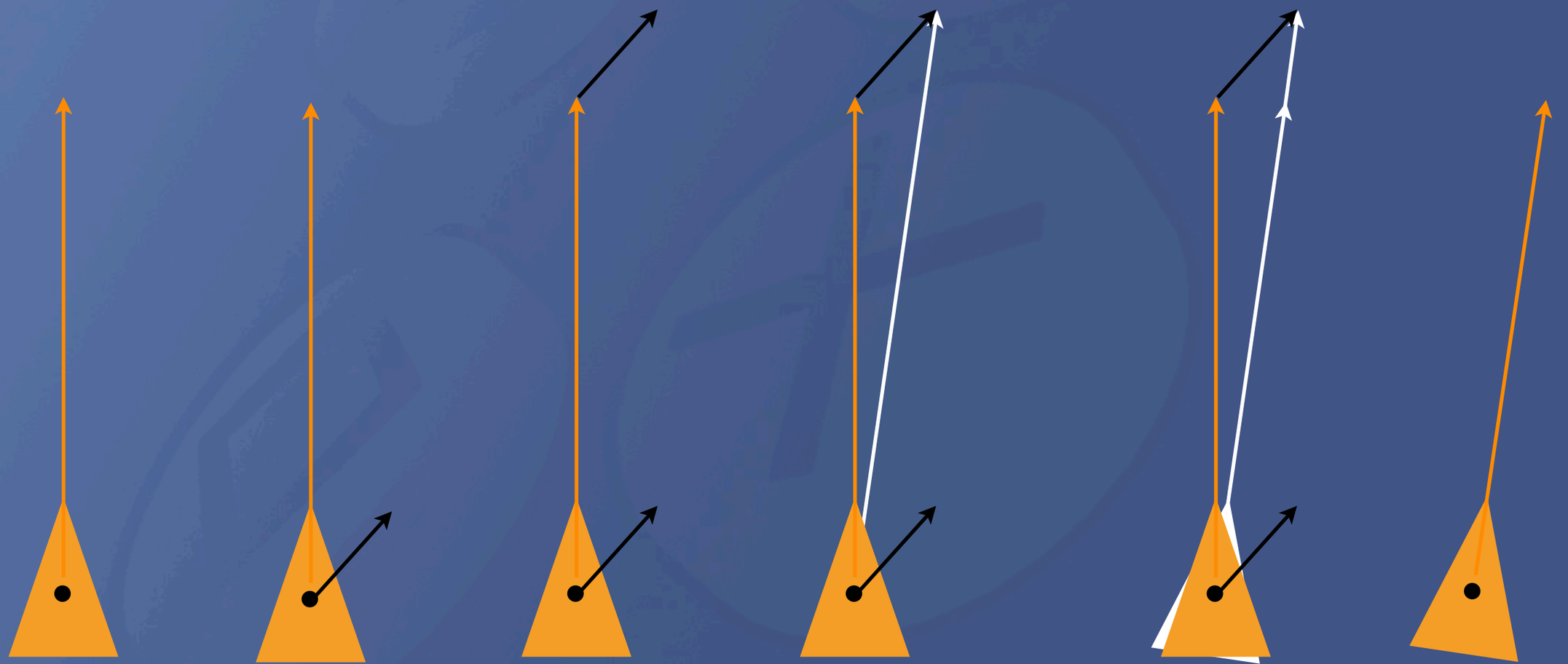
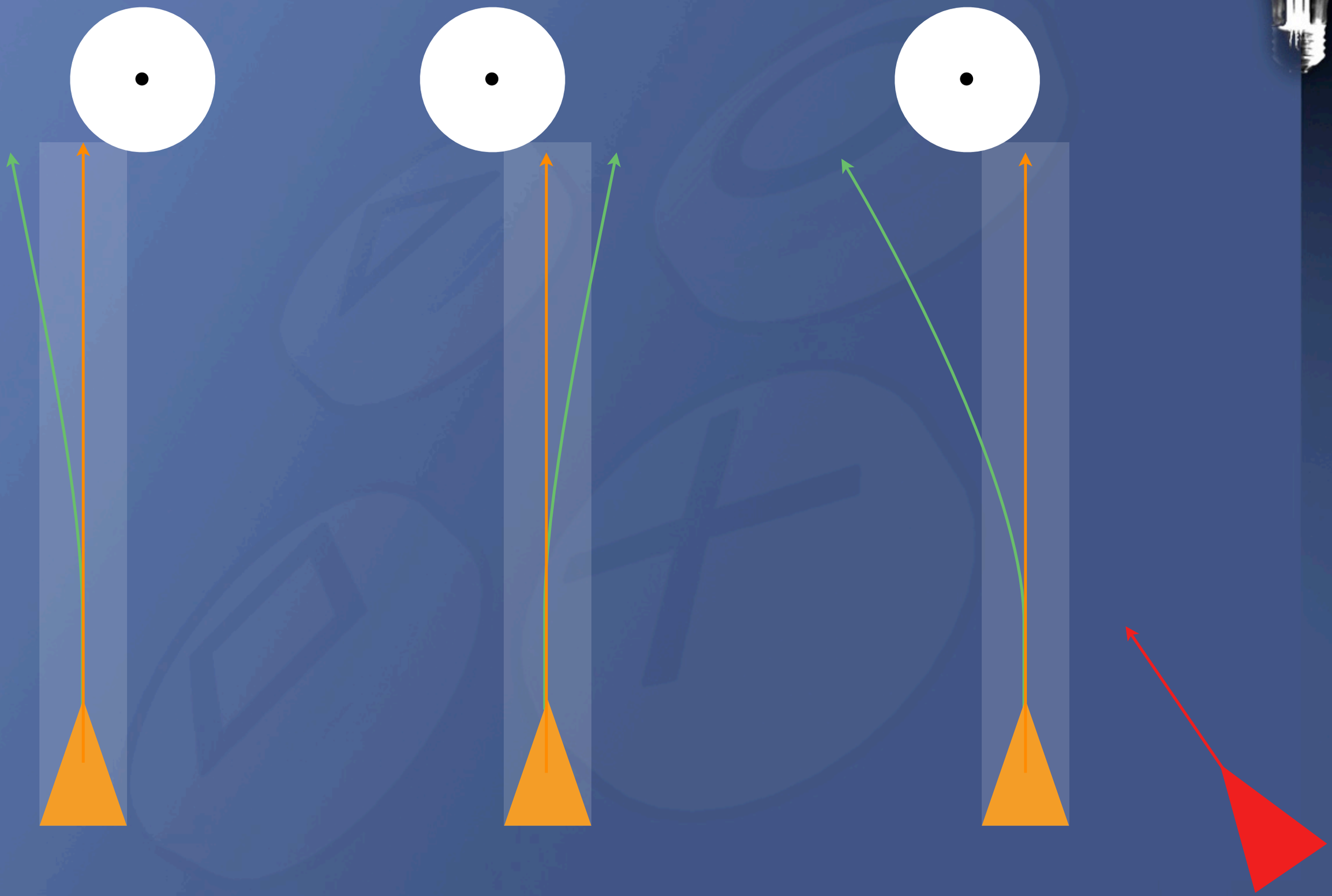
Steering behaviors

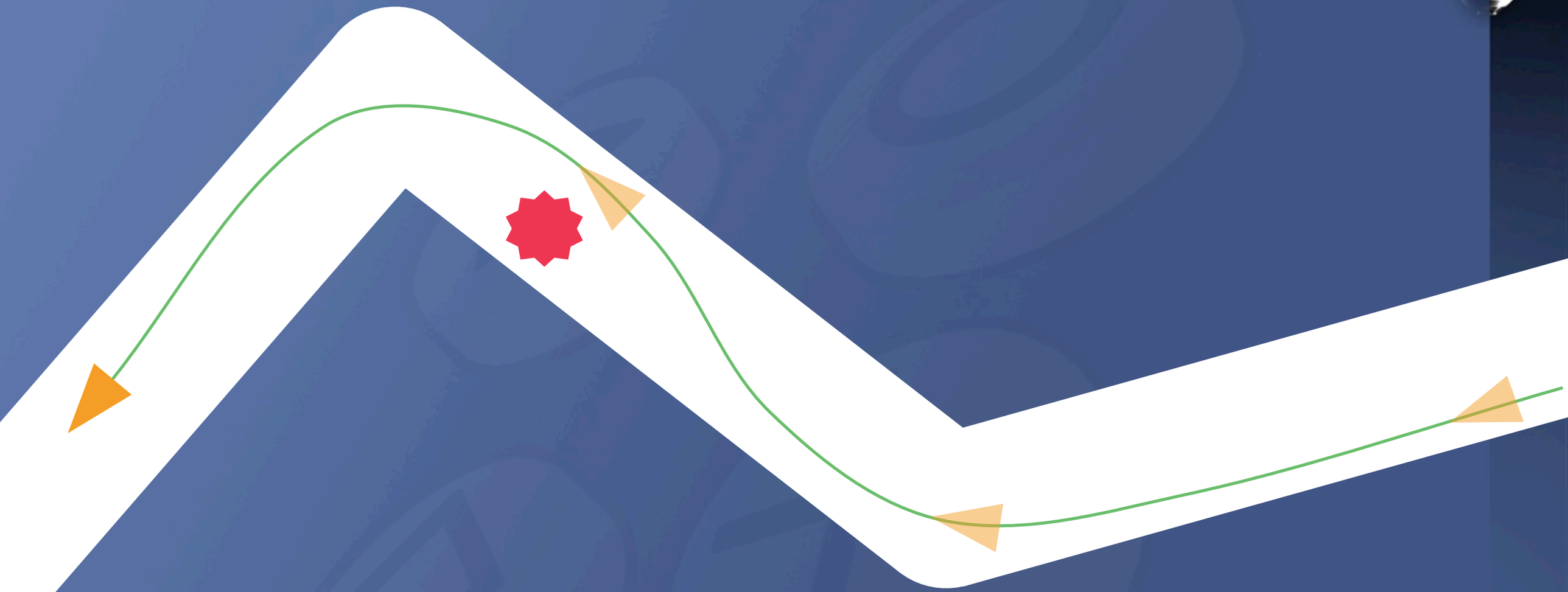
and simple point mass vehicles



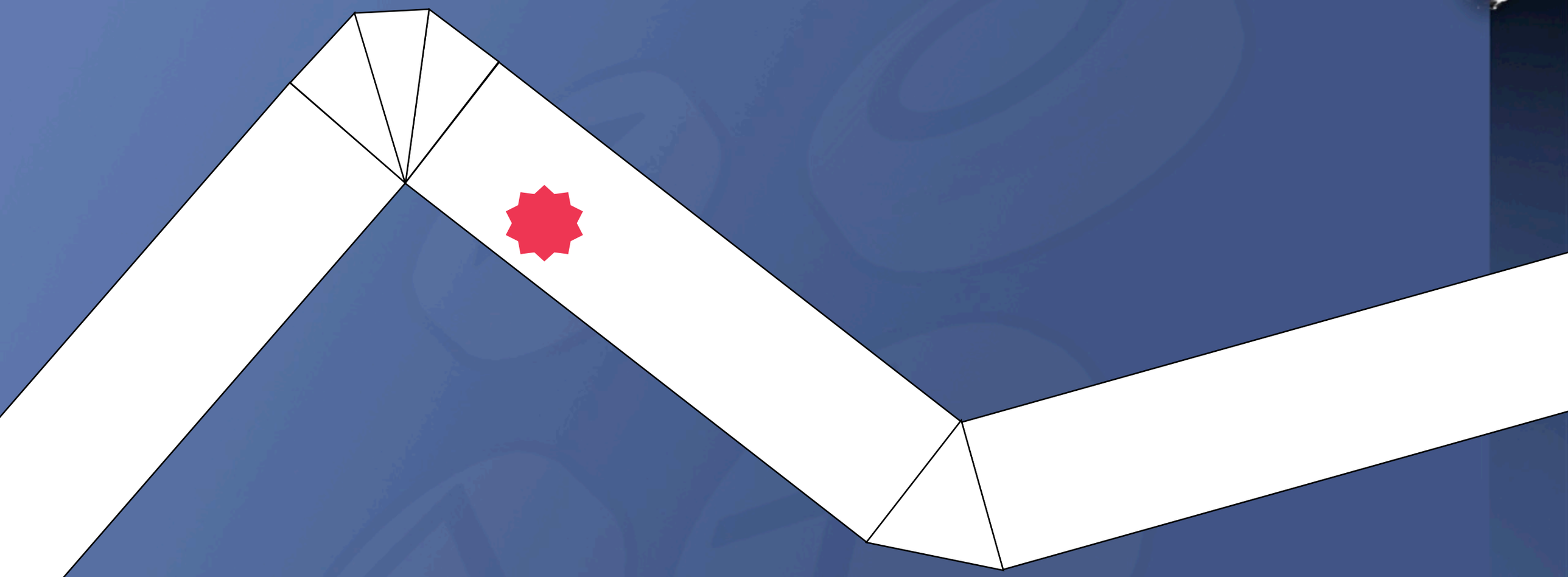
Steering behaviors

- seek / flee
- pursue / evade
- wander
- arrival
- avoid obstacle
- containment
- path following
- wall following
- flow field following
- flocking
  - separation
  - alignment
  - cohesion

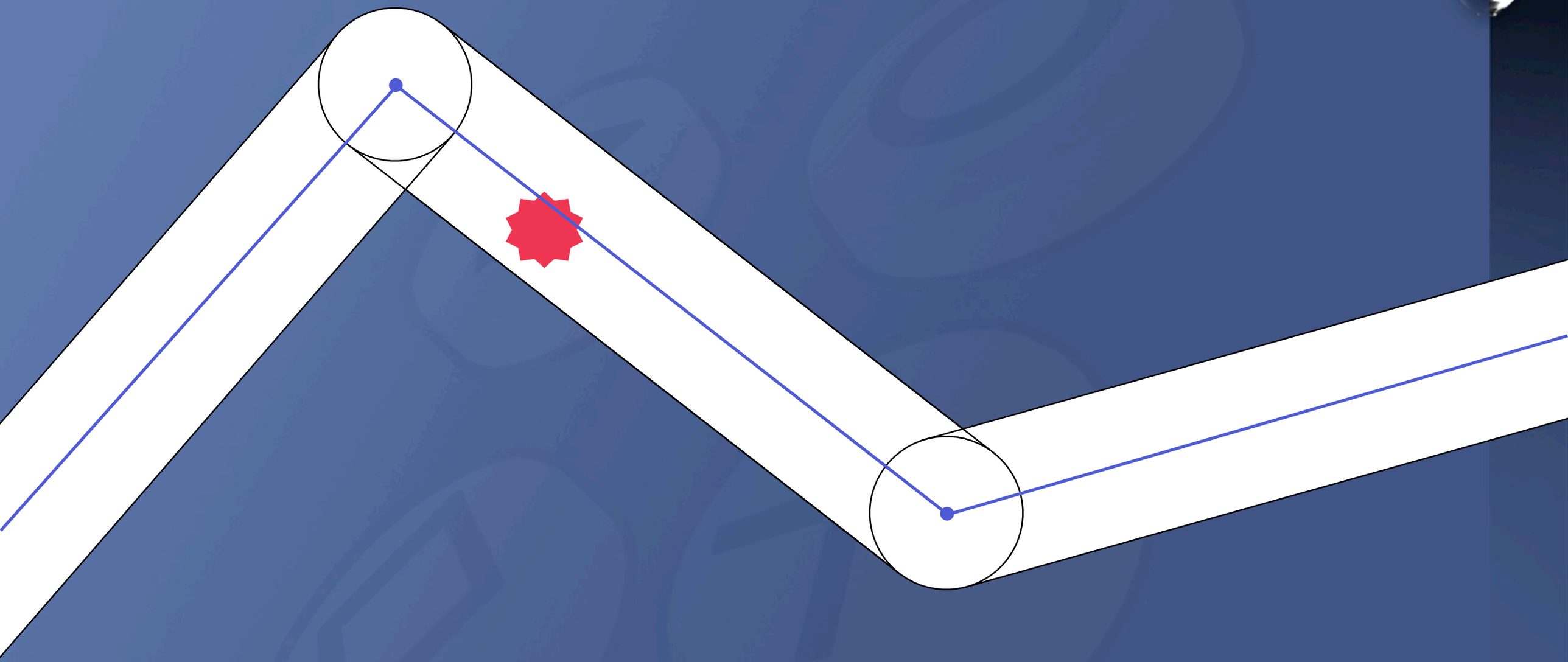




composed steering behaviors:
follow path and avoid obstacle



Navigation mesh

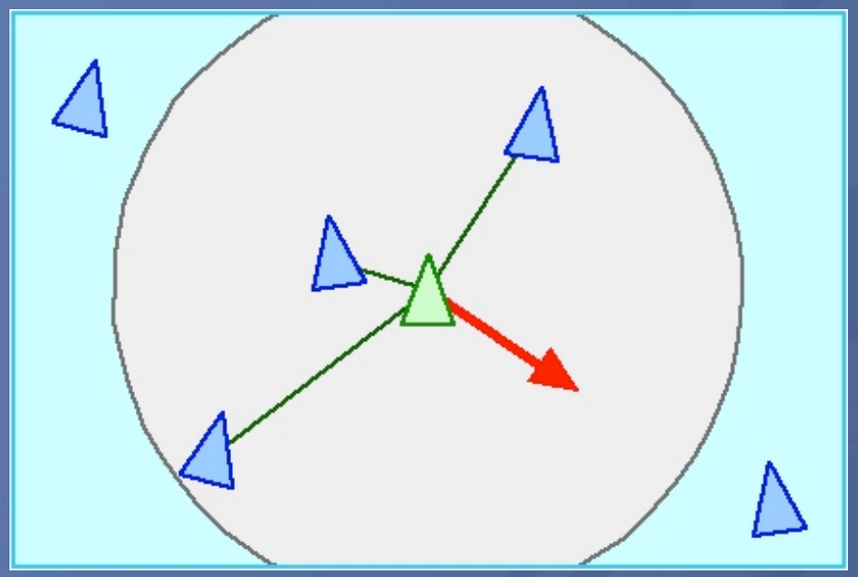


sphere swept along polyline

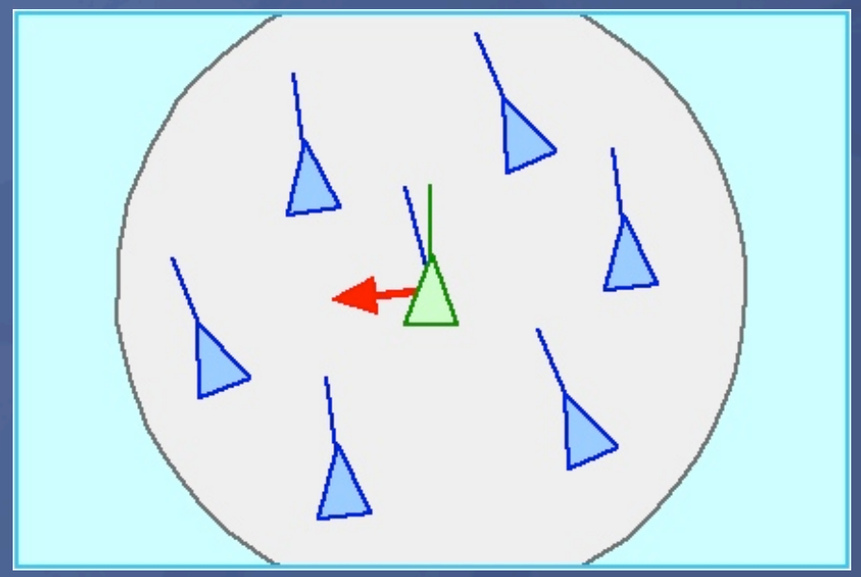
Flocks, herds, schools, crowds...

- 1987 boids model of group motion
- Early procedural animation of characters
- Applied to TV, movie and game production
- Focus was always on group motion

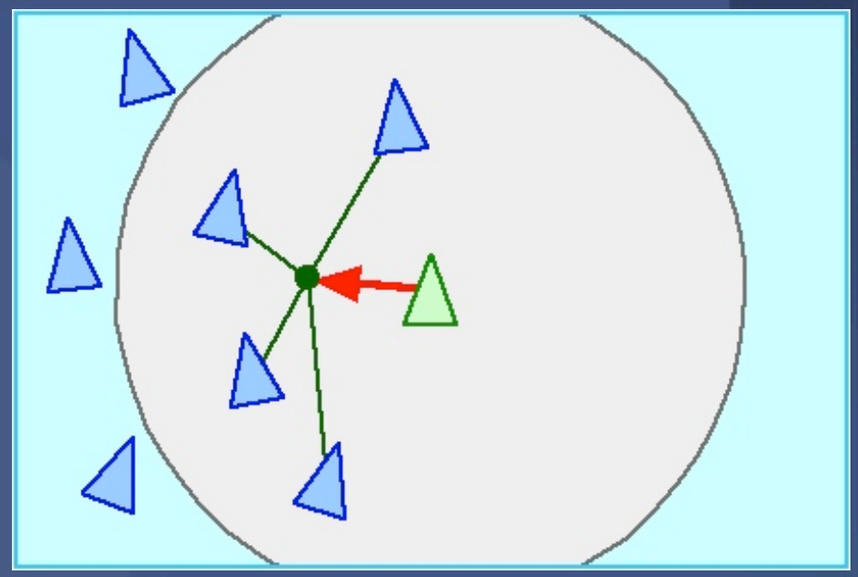
Flocking boids:
three component steering behaviors



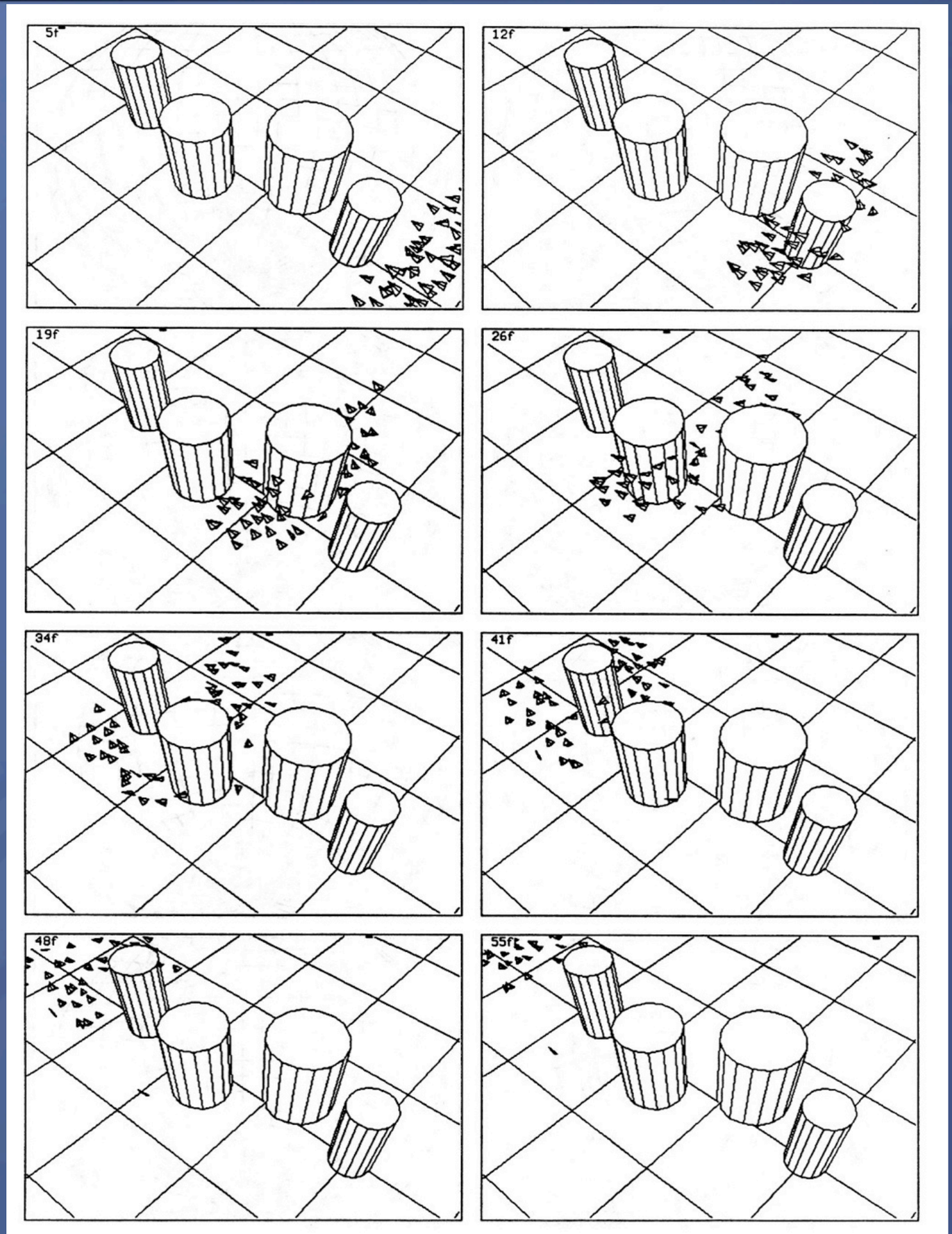
separation



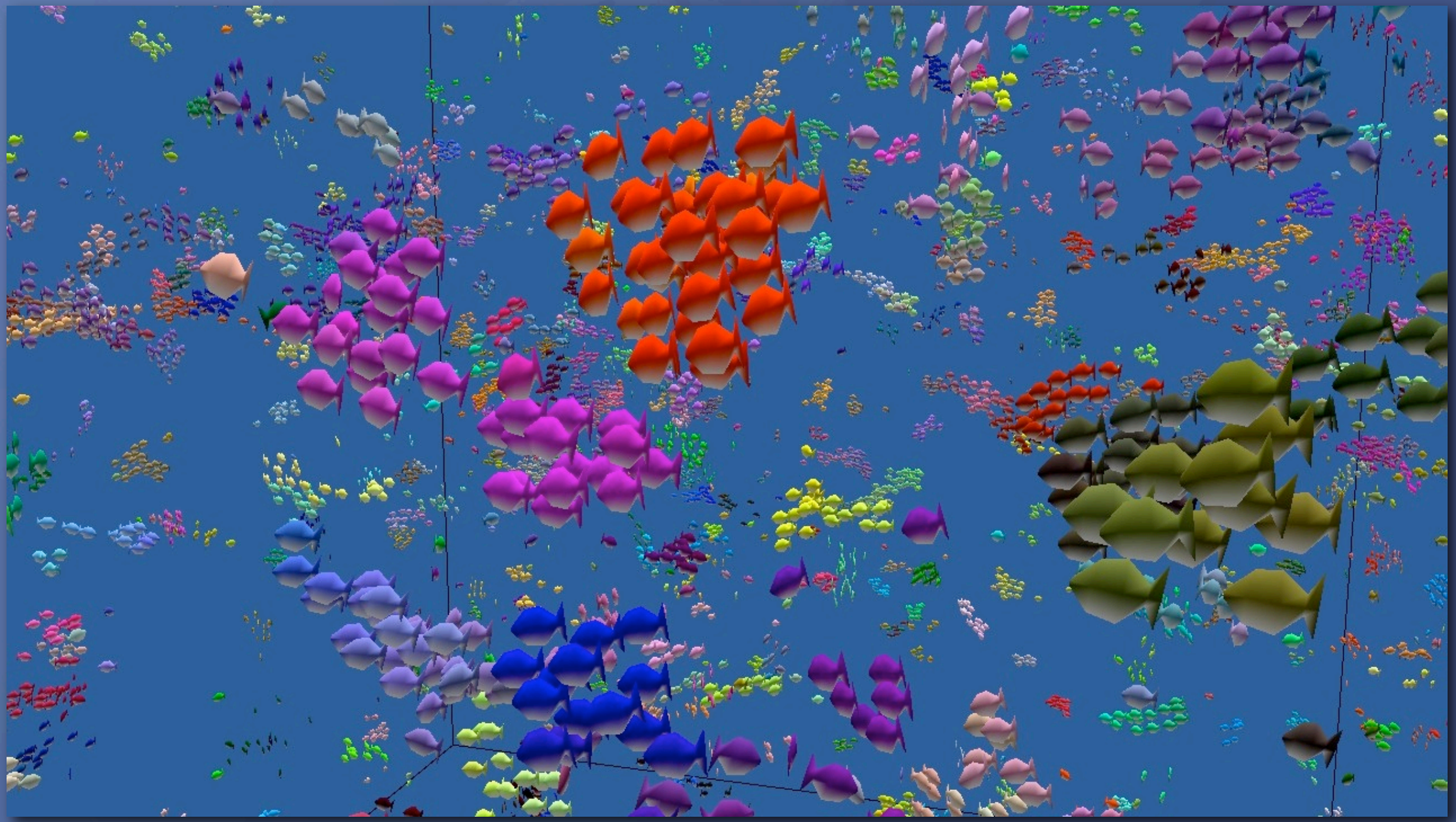
alignment

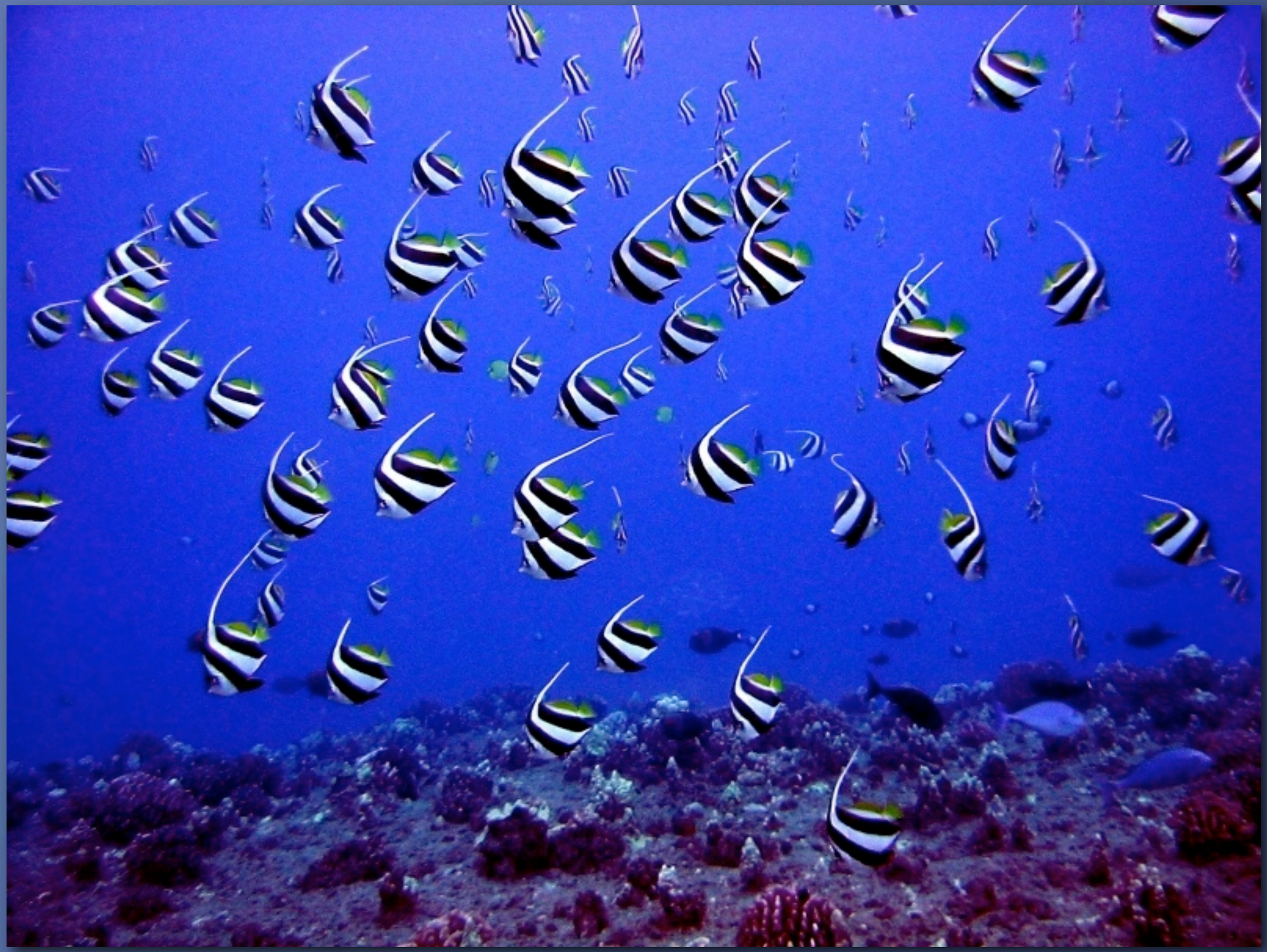


cohesion


5f
12f
19f
26f
34f
41f
48f
55f

PSCrowd
(video)





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Non-trudging crowds: what else do crowds do?

- Shoppers in a bazar
- Audience in a theater
- People at a party
- Players in a team sport
- Soldiers in combat
- Collective construction

Phulgalli market, India

Kuwait Stock Exchange

workers at Nash Motors during World War I

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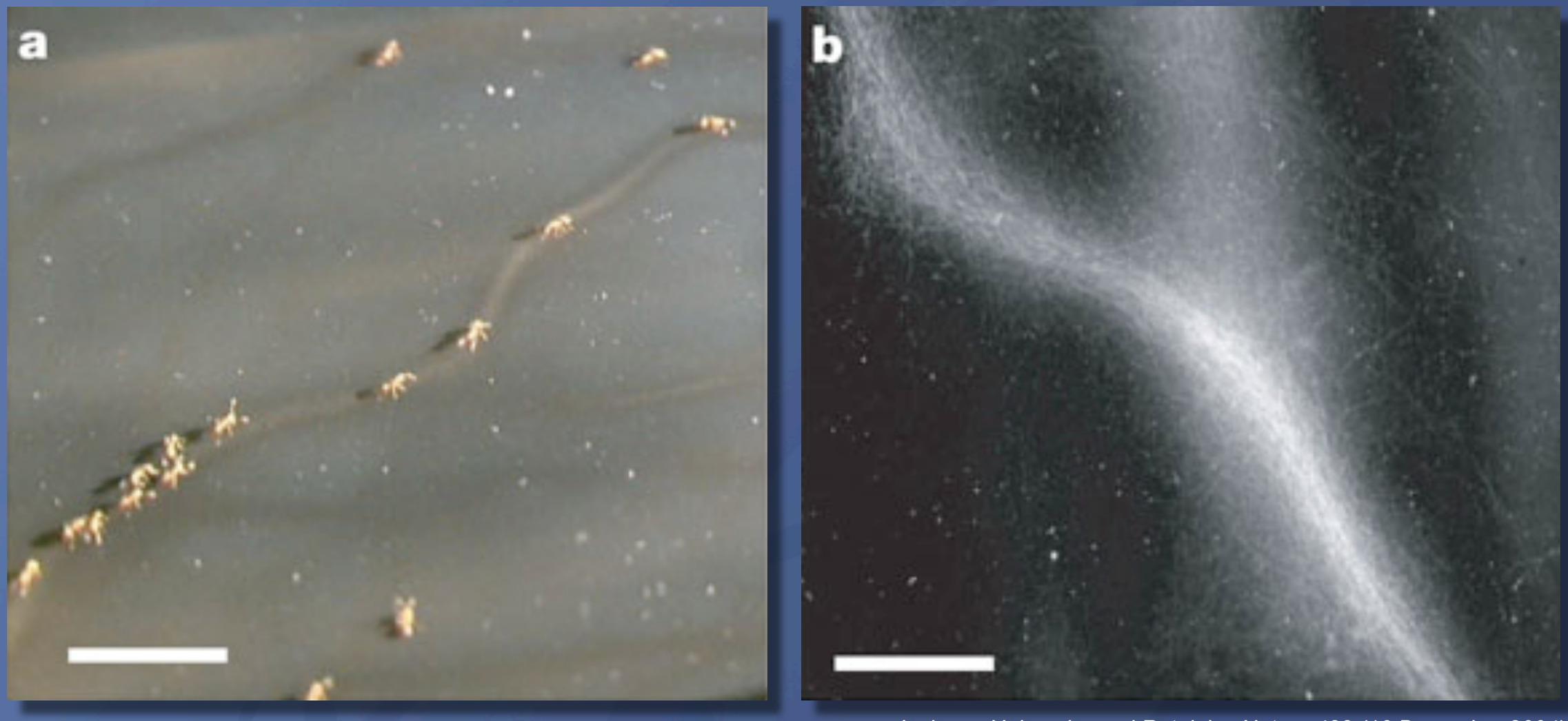
Emergent Teamwork in Nature

Collective foraging: exploration and retrieval



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

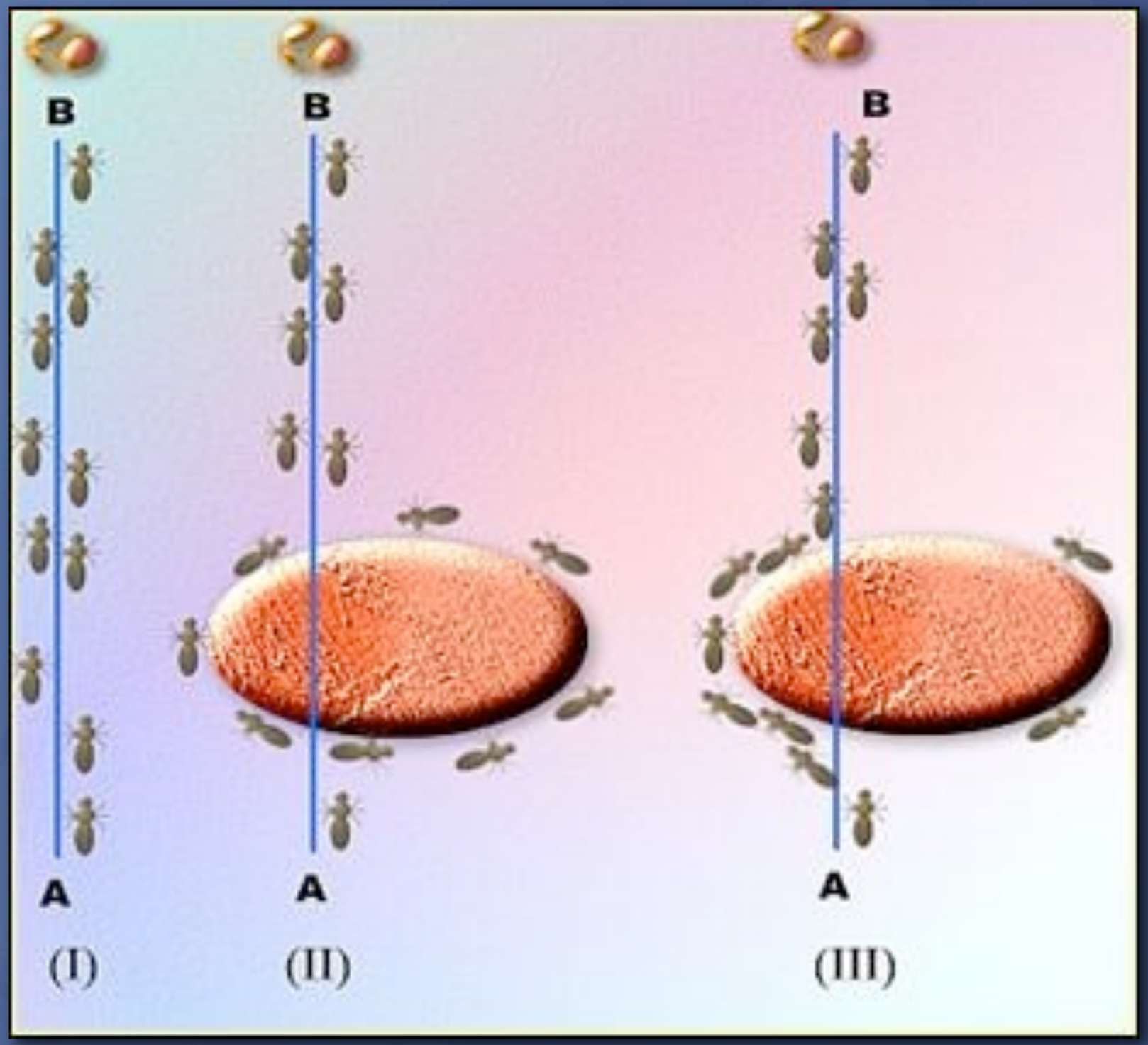
Pheromone trail networks of Pharaoh's ants on a smoked glass surface

Collective transport: optimizing traffic flow

Scott Powell and Nigel Franks, in Animal Behaviour, 2007

Army ants covering “potholes” with their own bodies

Collective decision making: optimizing path length



http://ljs.academicdirect.org/A09/053_072.htm

Collective porting: carrying large objects

Staub Family in Brazil (blog post July 19 2006)

Nik Daum (blog post Nov 2, 2005)

Collective construction

Collective construction: humans build brick wall

- obvious where to place next brick
- add more people to build faster
- may use language to coordinate

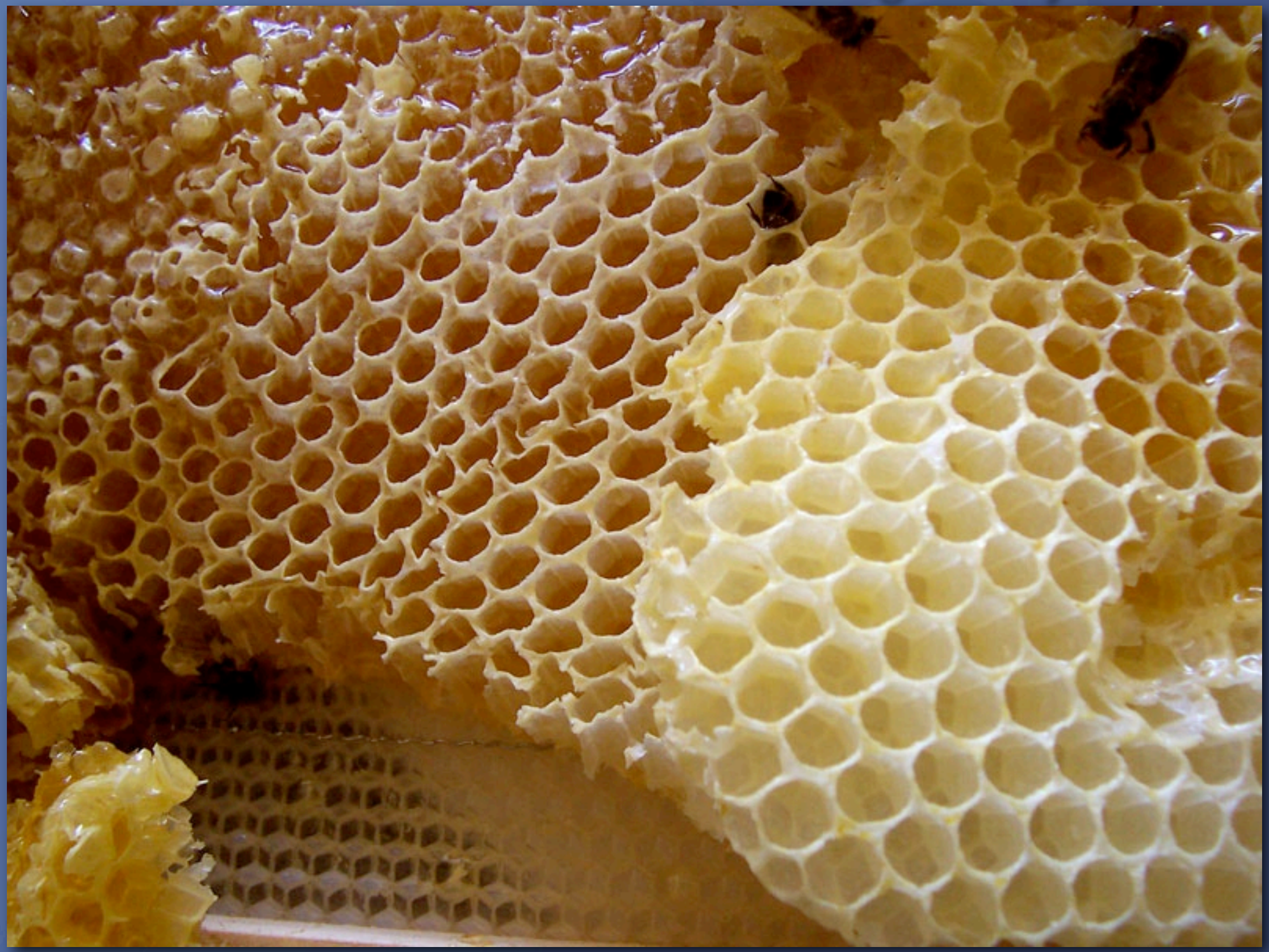
Stigmergy

- 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)

Collective construction: nest building by birds

collective nest building, ©2006 Stephen Carl Baldwin, BrooklynParrots.com

Collective construction: bees building honeycomb



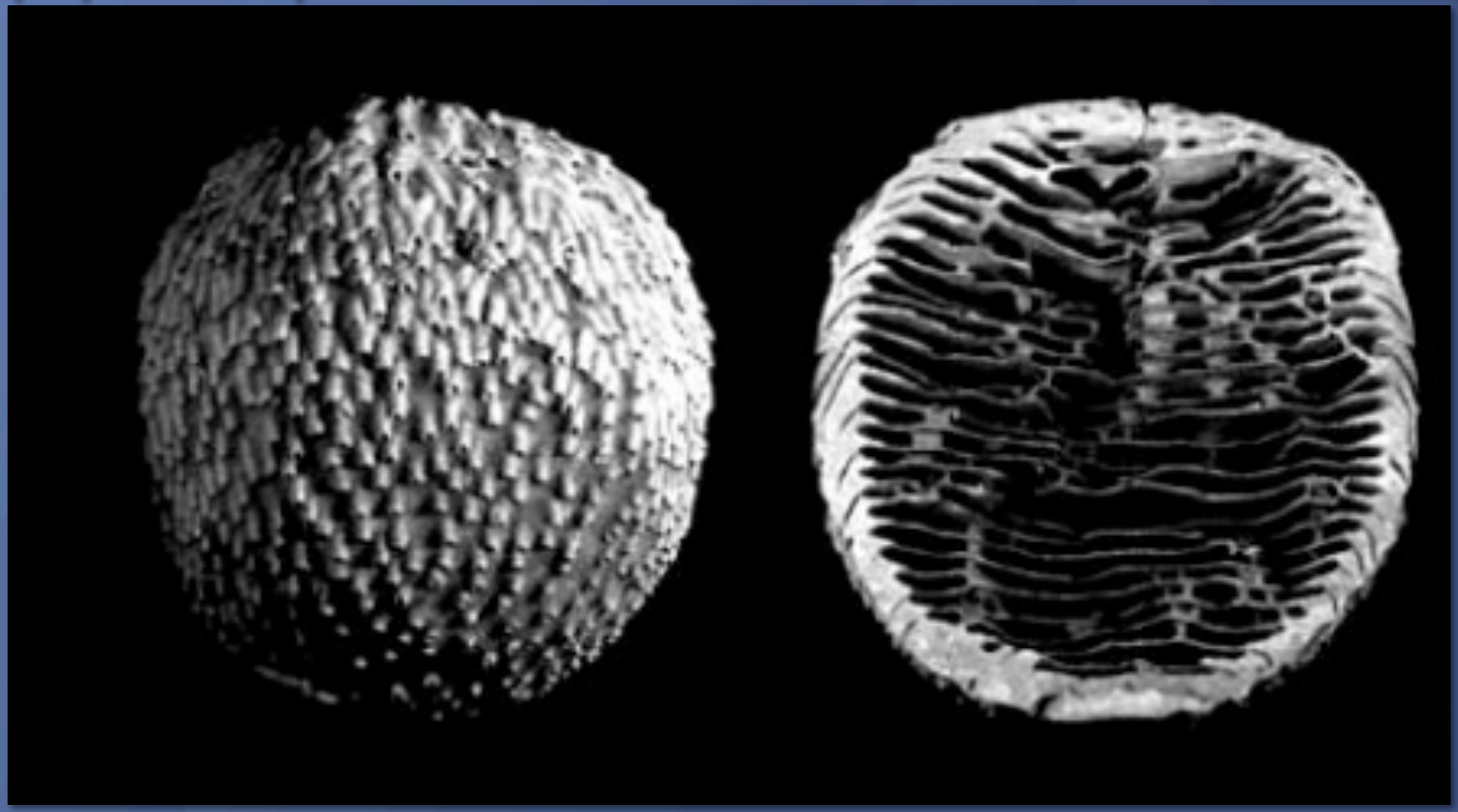
Paper wasp nest

Paper wasp by Natasha Mhatre via Flickr

Potter wasp nest

Potter wasp by Natasha Mhatre via Flickr

Collective construction: paper wasp nest cross-section



Garnier, Gautrais, Theraulaz (2007) The biological principles of swarm intelligence, Swarm Intelligence

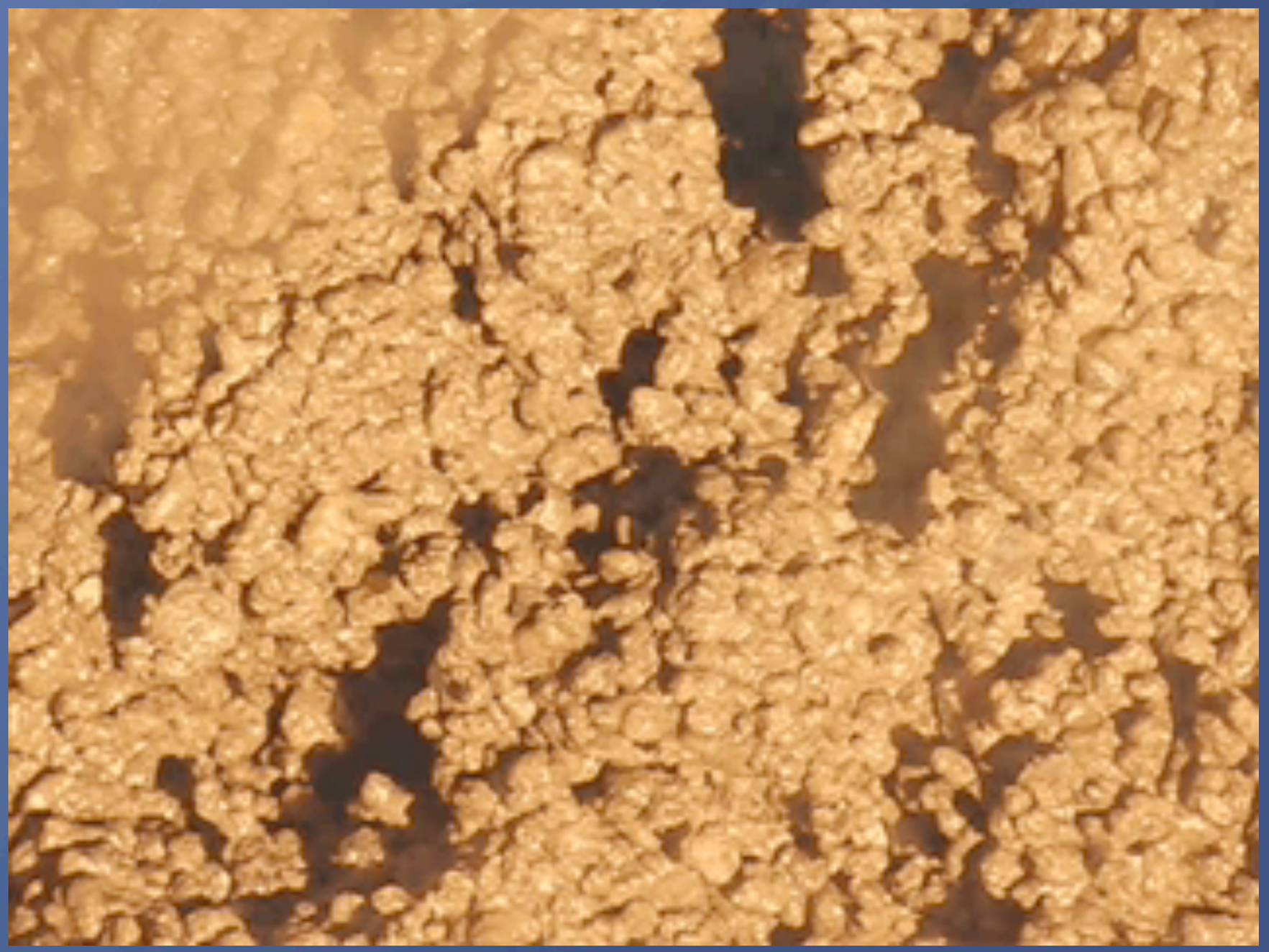
Collective construction: termite mound size

Collective construction: termite mound abundance

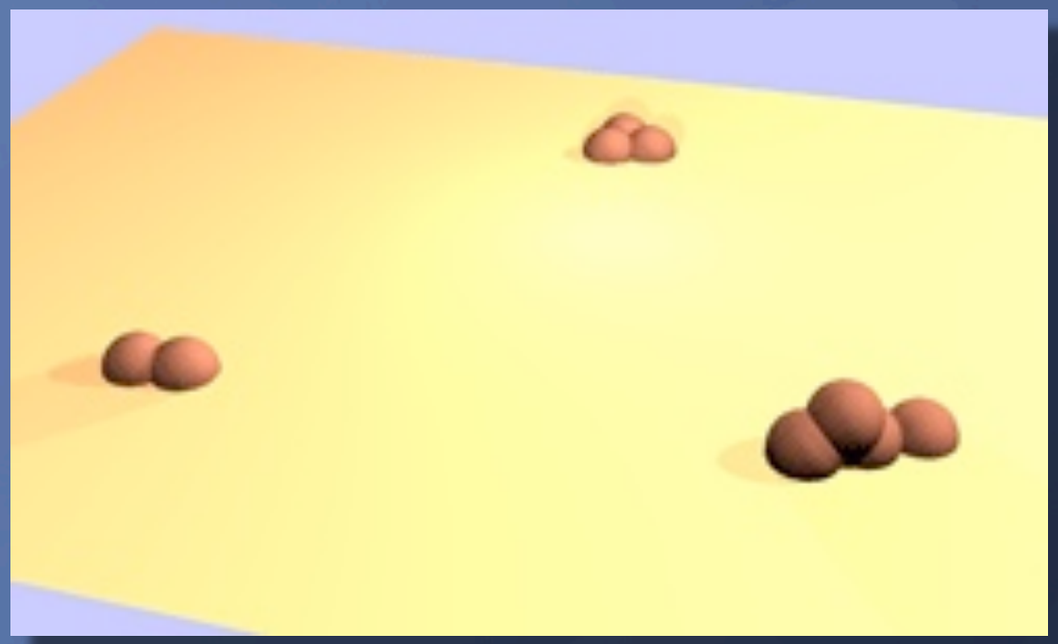
Collective construction: micro structure of termite mounds

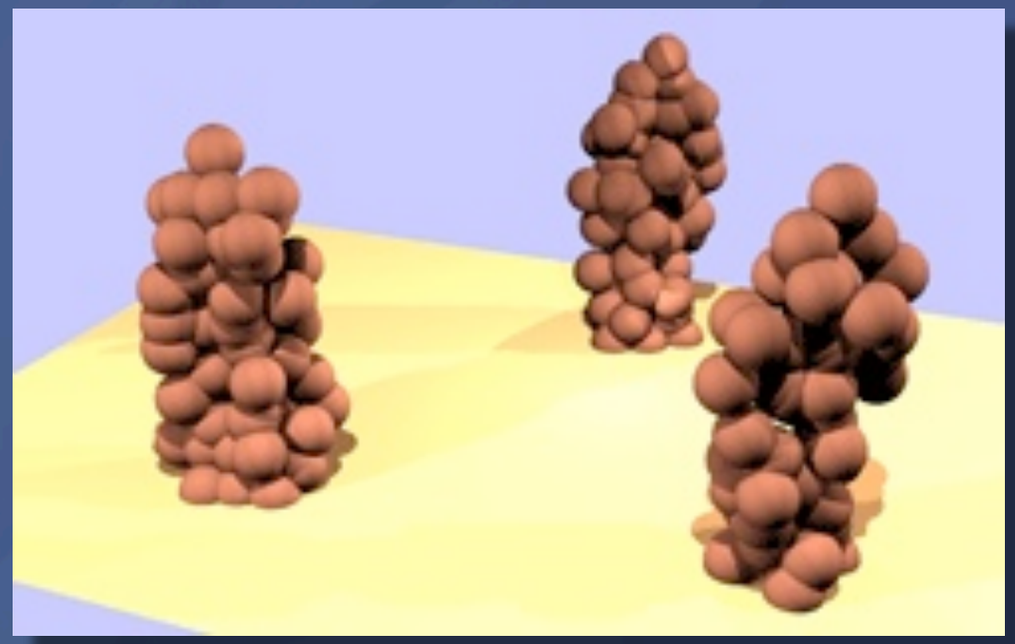
Scott Turner, SUNY Syracuse, used with permission

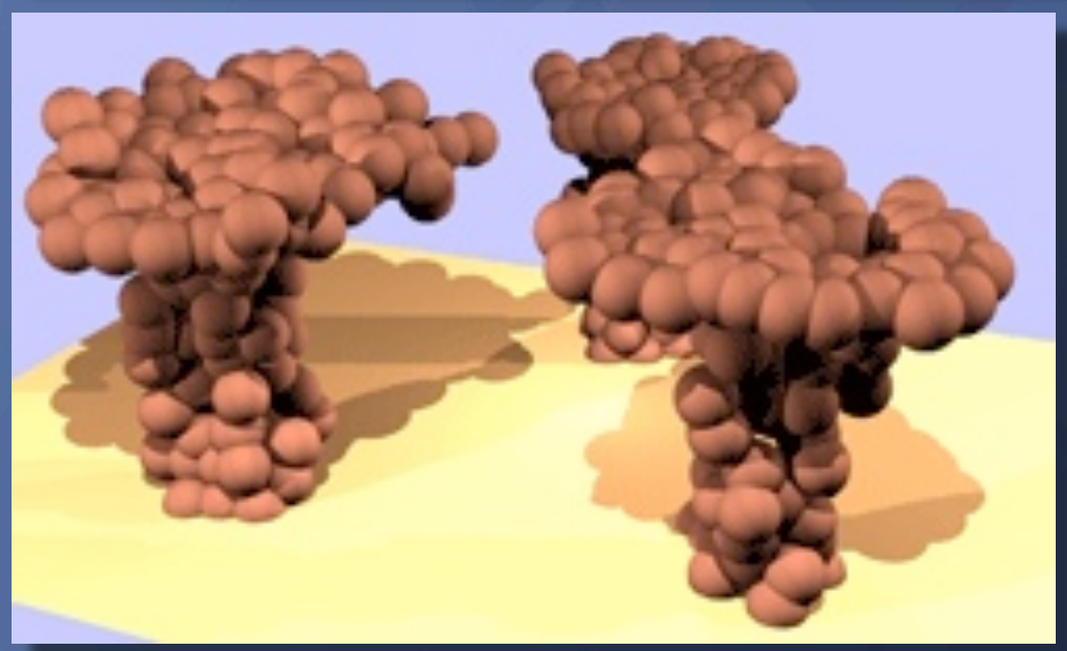
Termites repair mound with “spongy build”

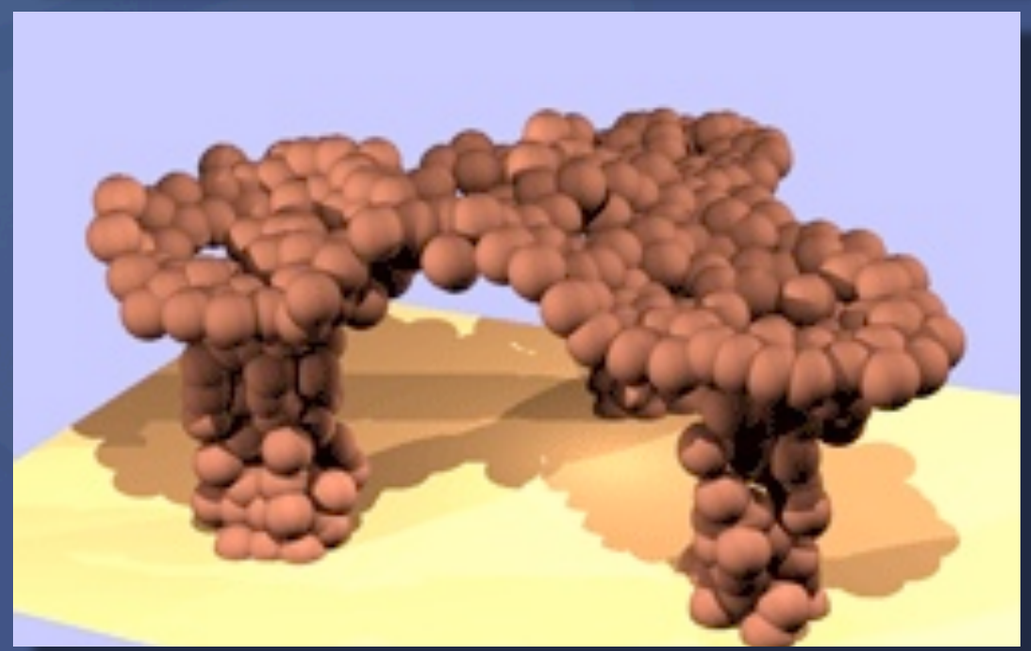


Termite stigmergic building: pillar construction and the roofed gallery



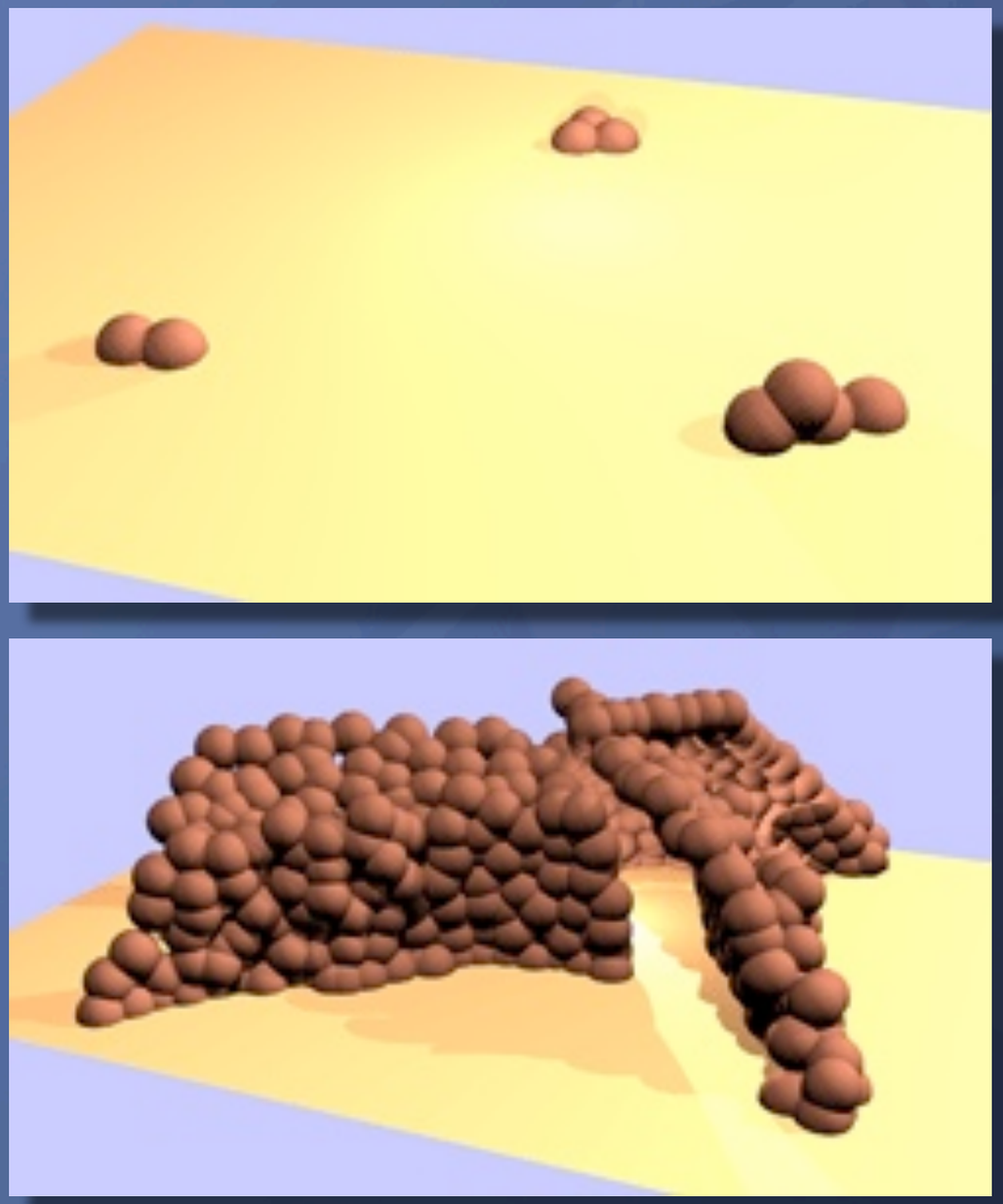


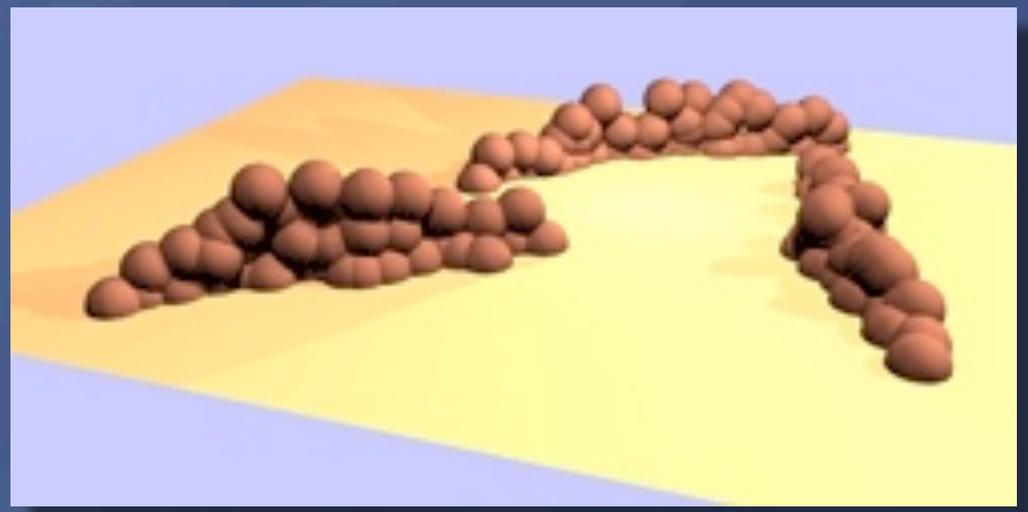


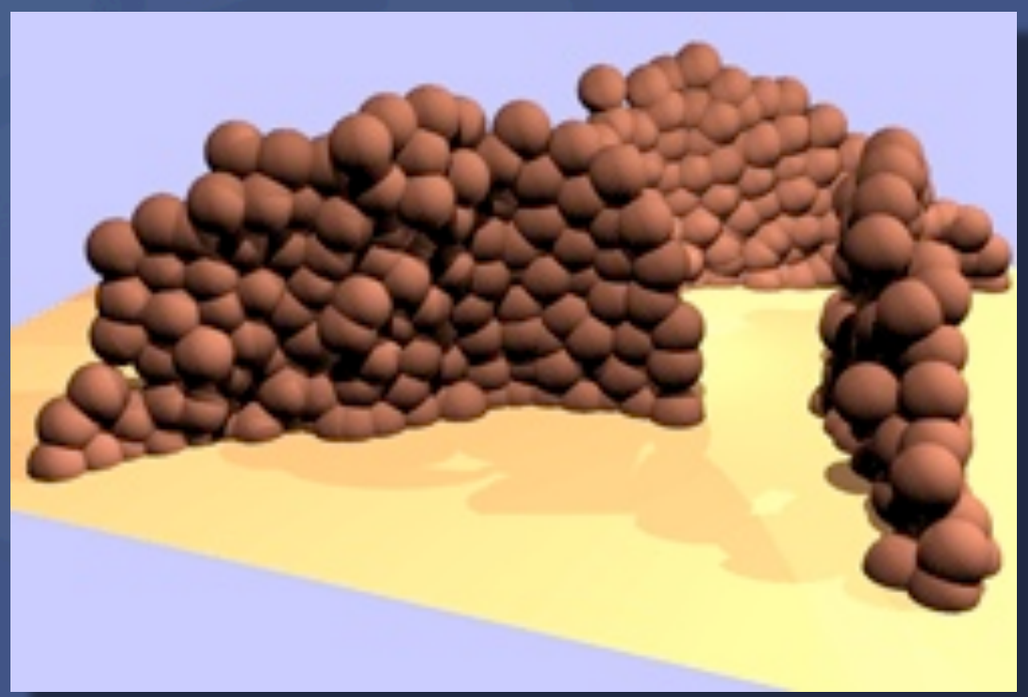


Scott Turner, SUNY Syracuse, used with permission

Termite stigmergic building: Wall construction and enclosure of space



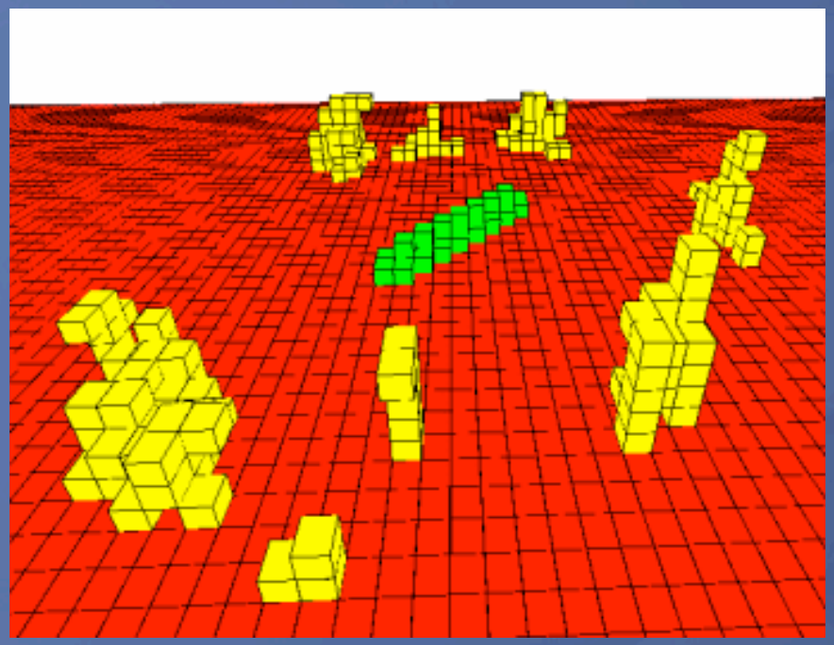


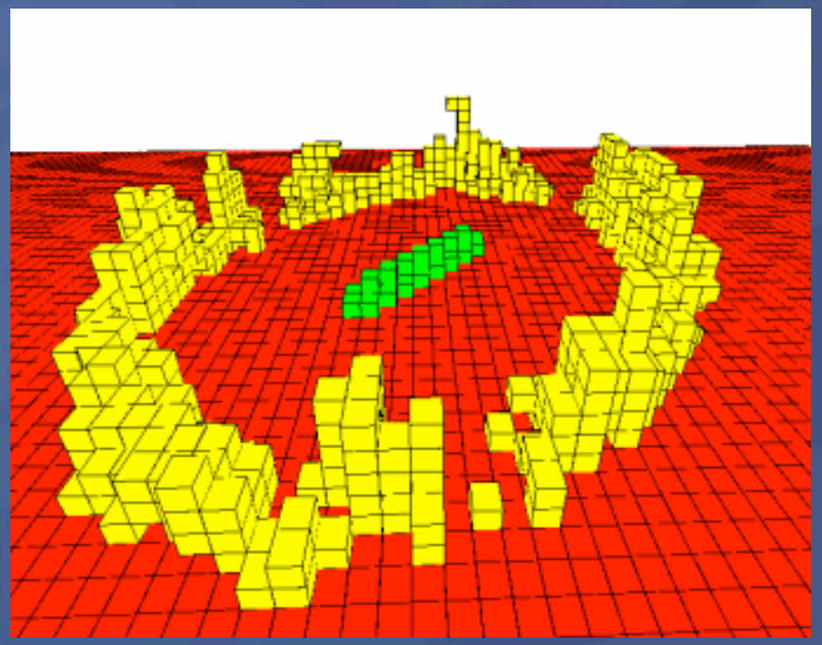


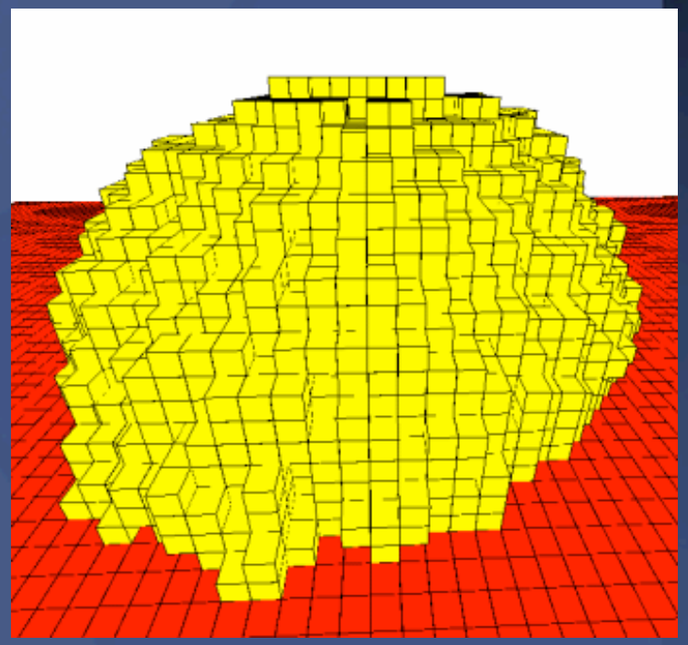
Scott Turner, SUNY Syracuse, used with permission

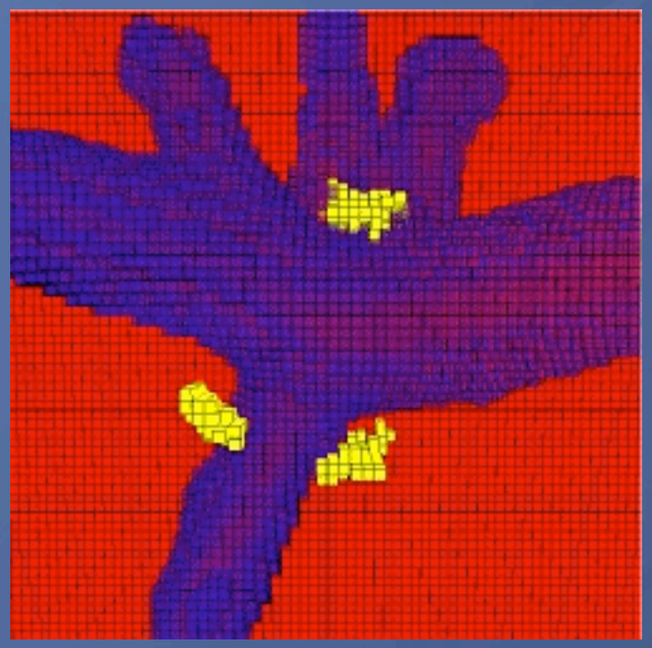
Collective construction:
previous simulation results by other authors

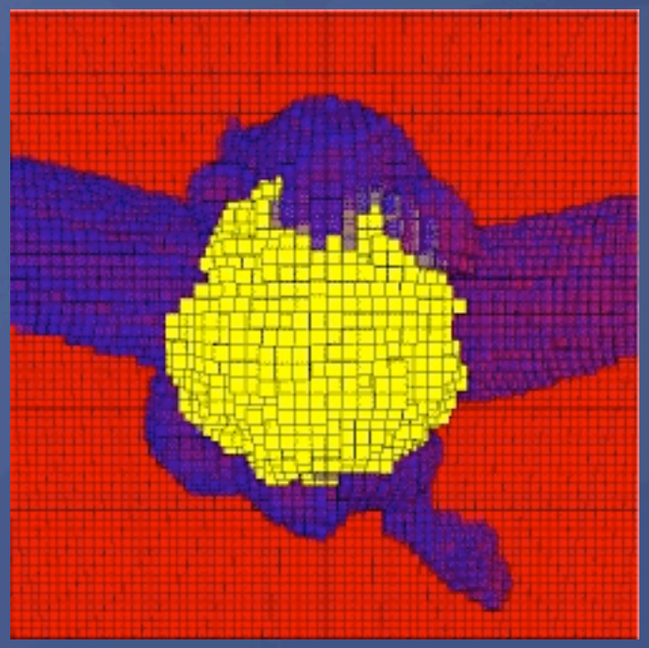
The role of logistic constraints in termite construction of chambers and tunnels

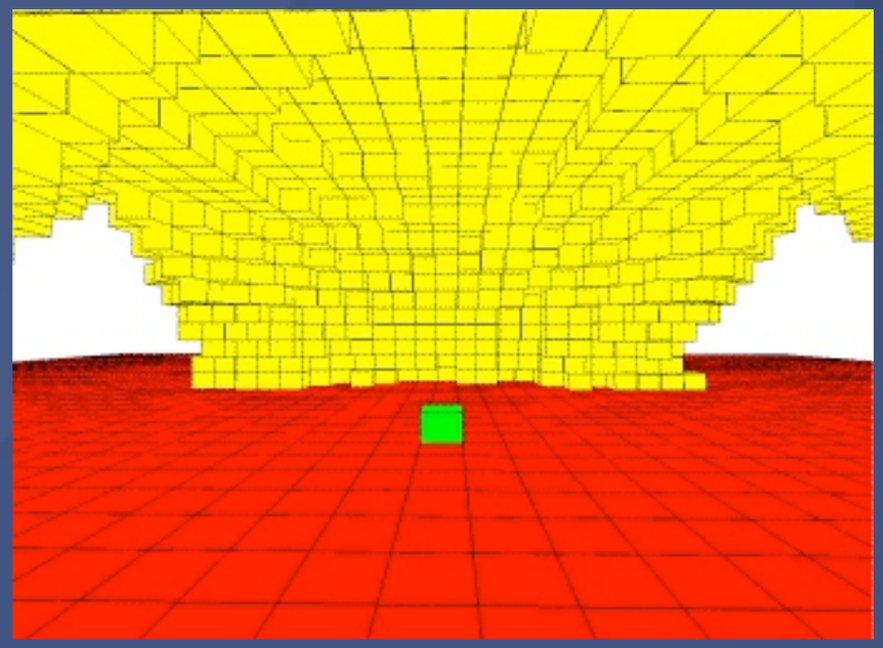






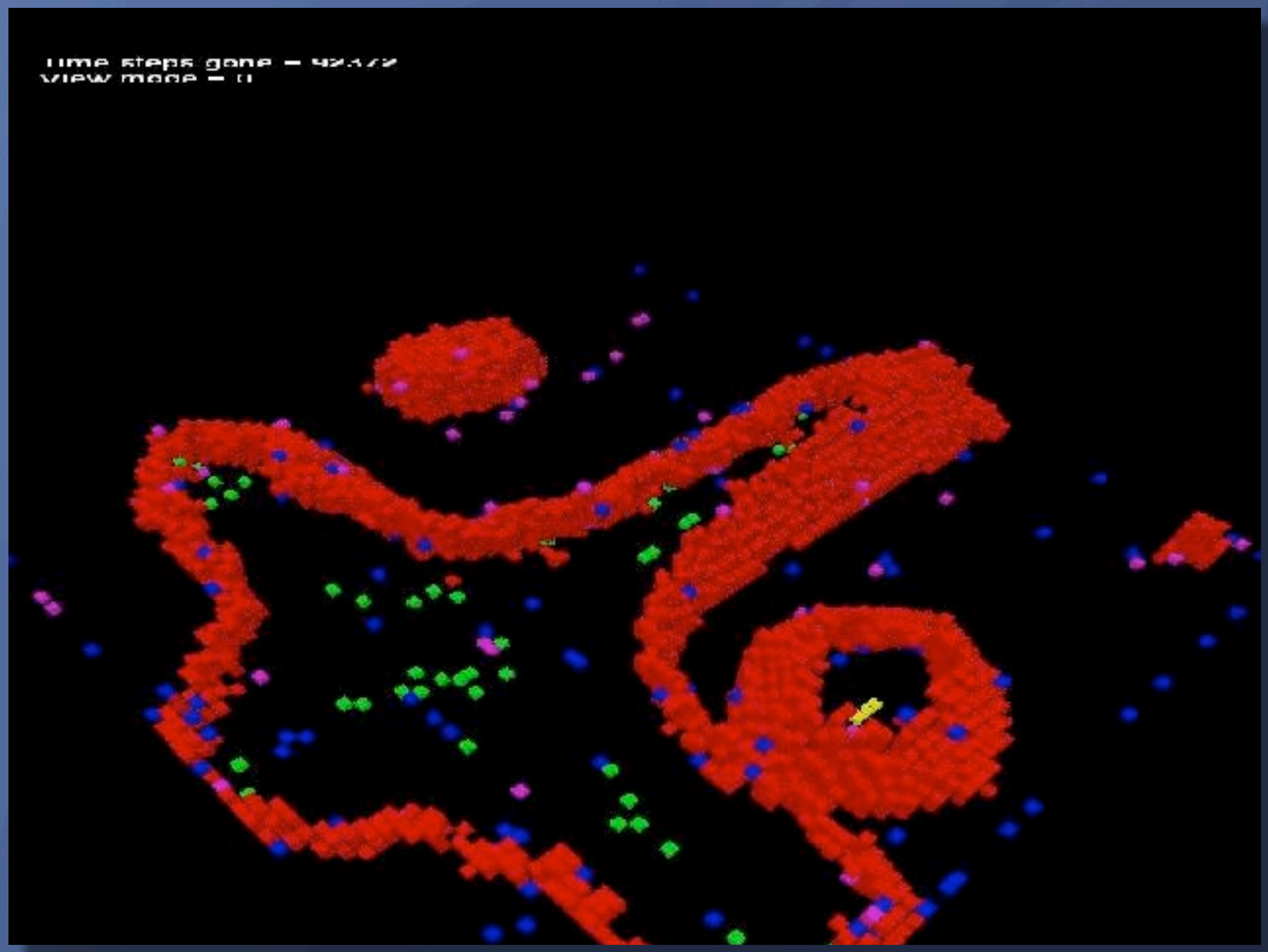






Ladley and Bullock, Journal of Theoretical Biology, 2005

Termite model: discrete voxel space



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

Collective construction:
my recent experiments

Construction with “bricks”

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

Progression of models

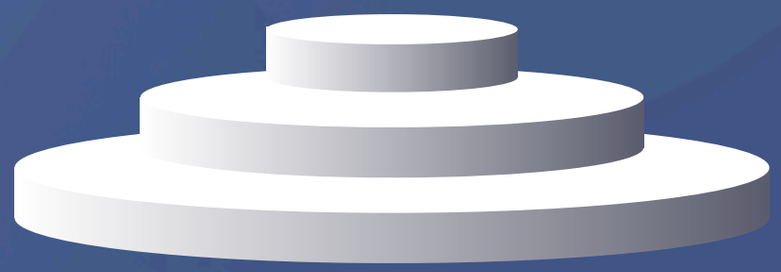
- Central disk building
- Central tower building
- Emergent tower building

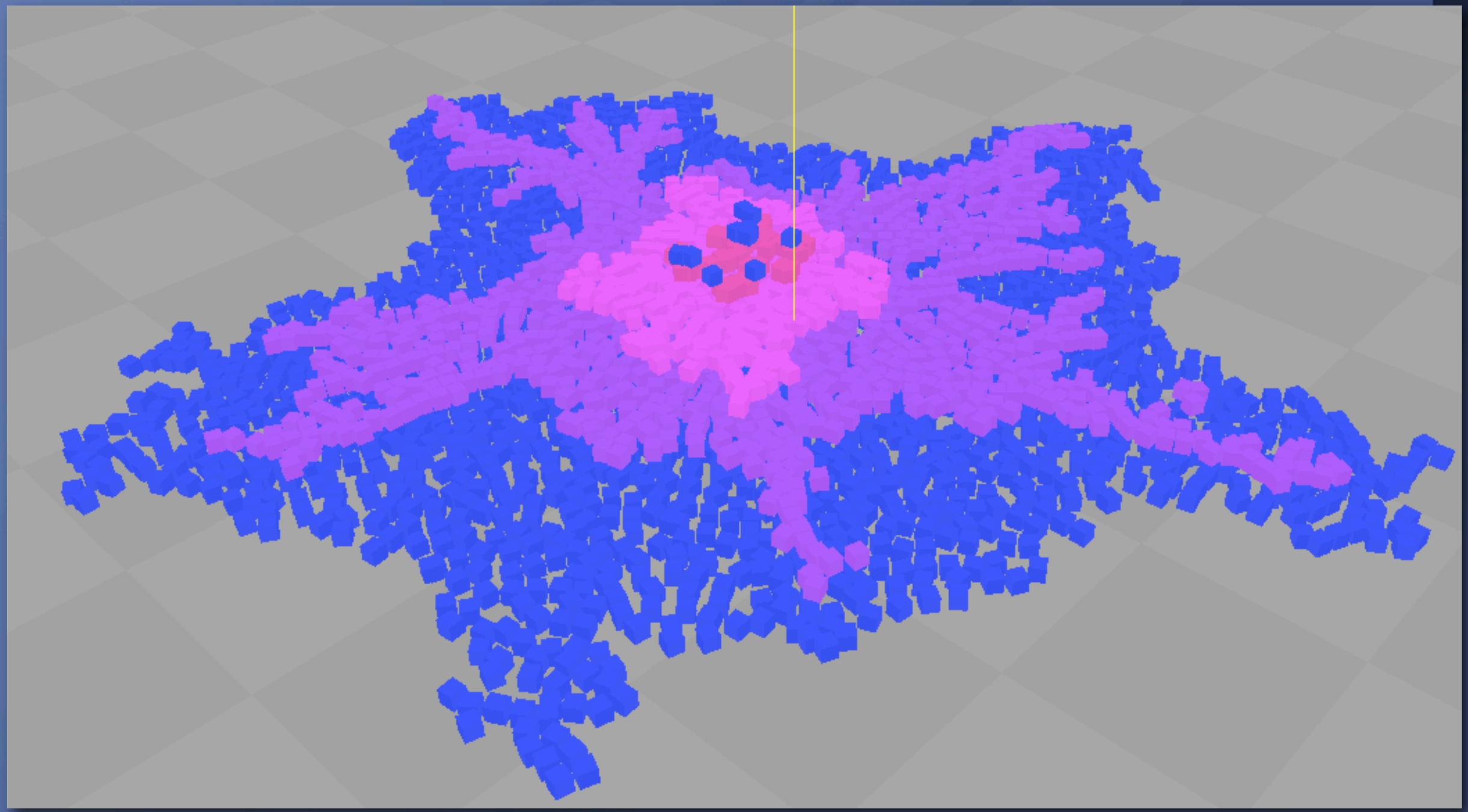
Disk construction

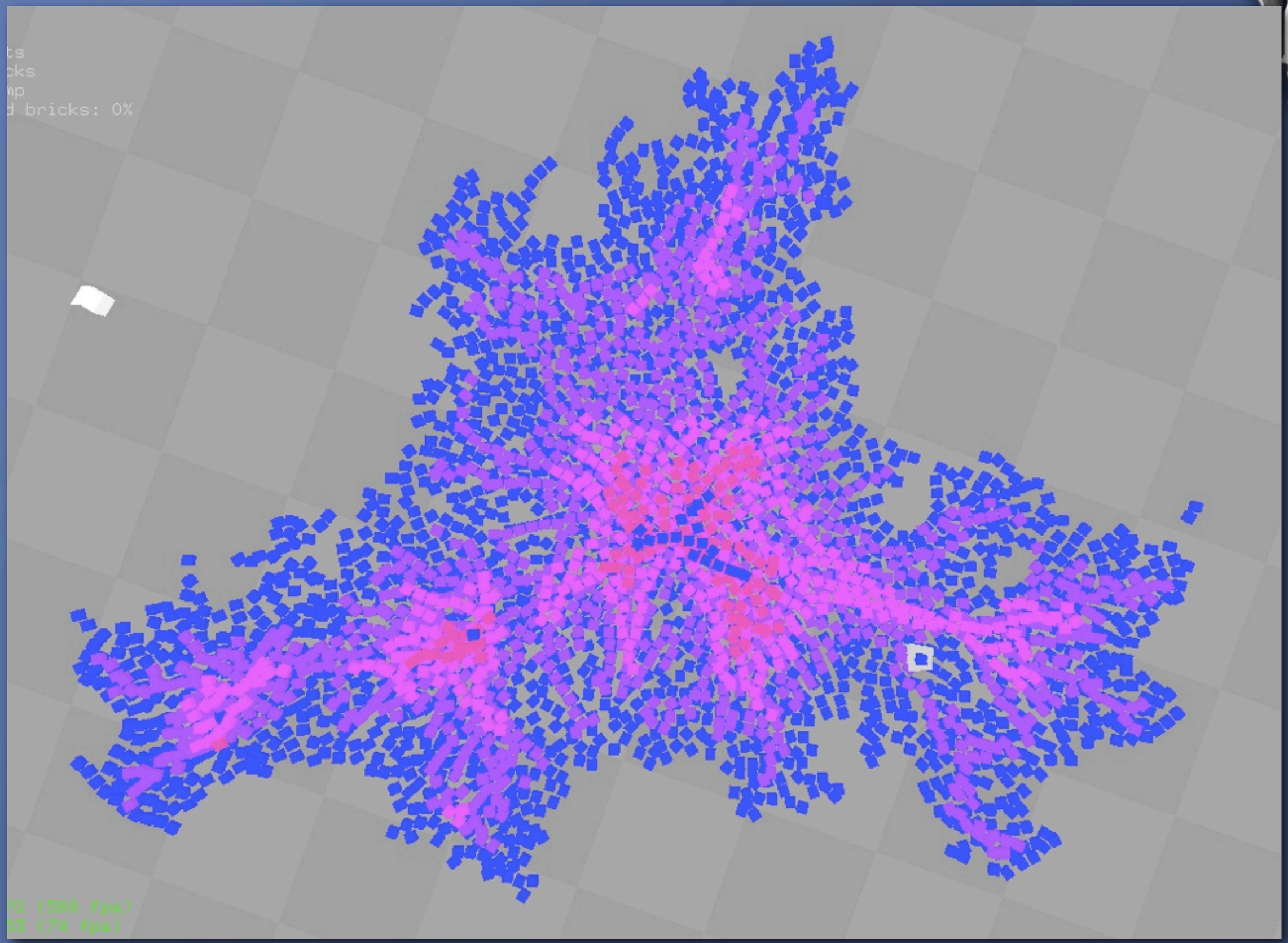
- Forage for bricks
- Return to edge of construction site
- Deposit brick near edge of disk
- Repeat...

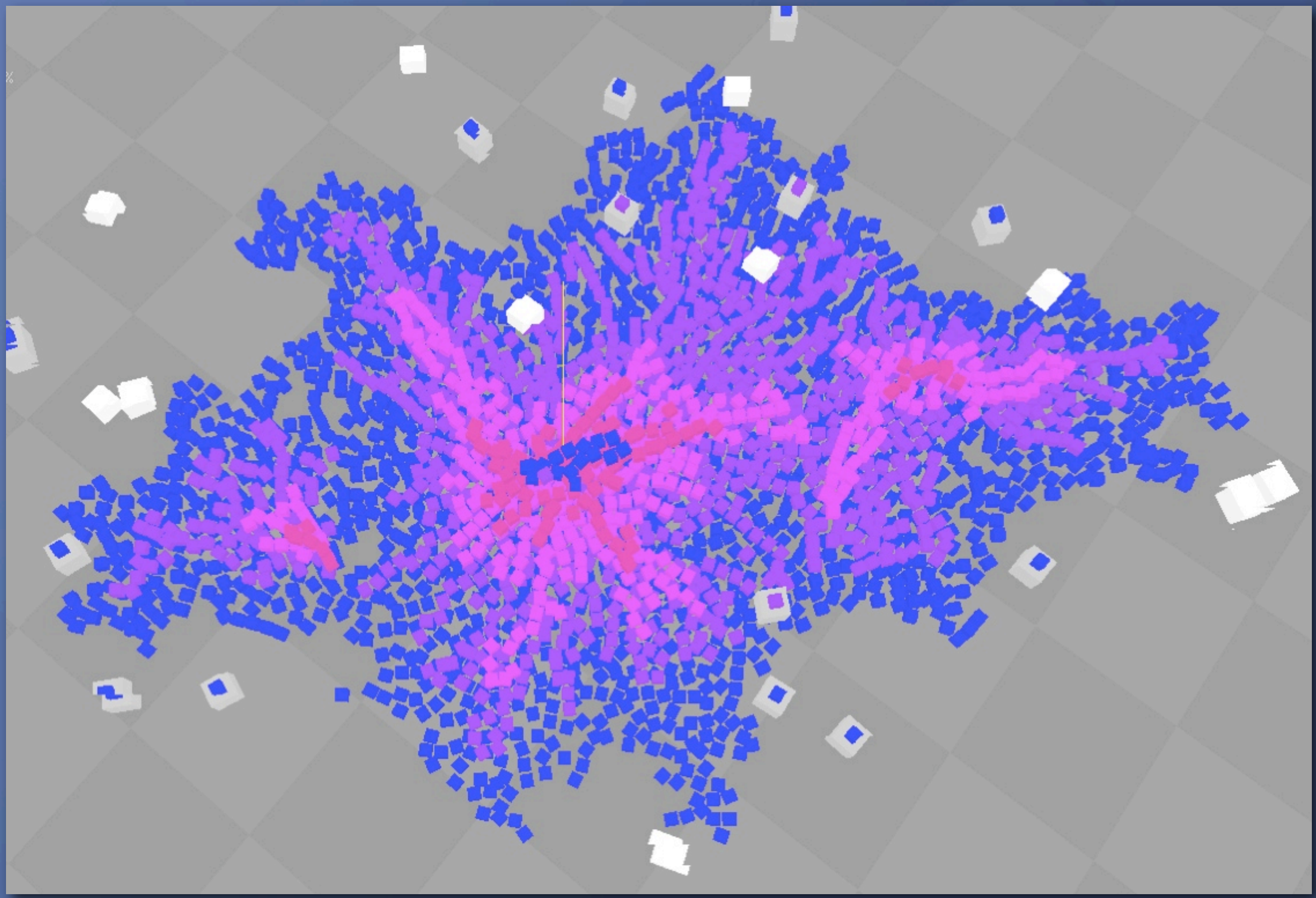
Heap construction

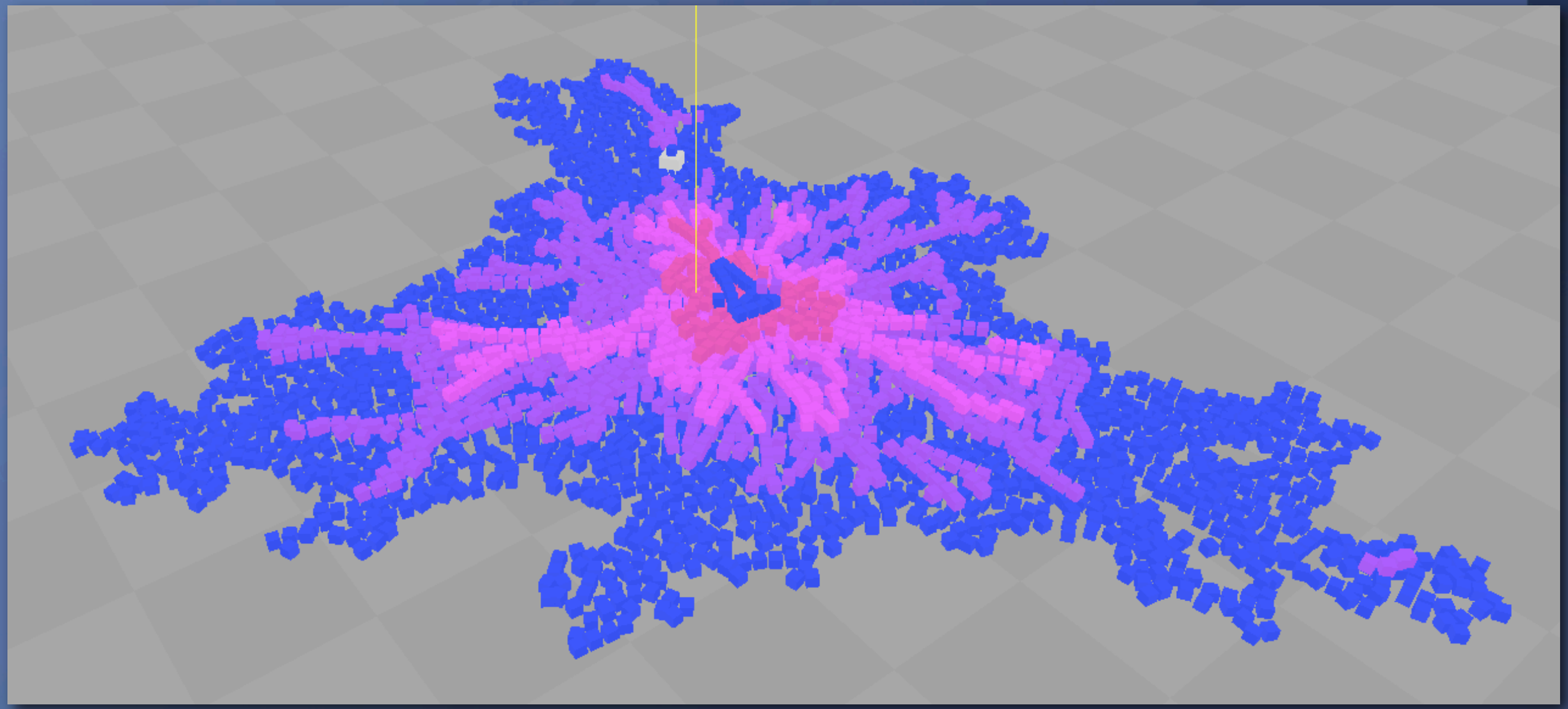
- Forage for bricks
- Return to edge of construction site
- Choose one of:
  - Deposit brick near edge of disk
  - Jump on top of disk, then deposit
- Repeat...

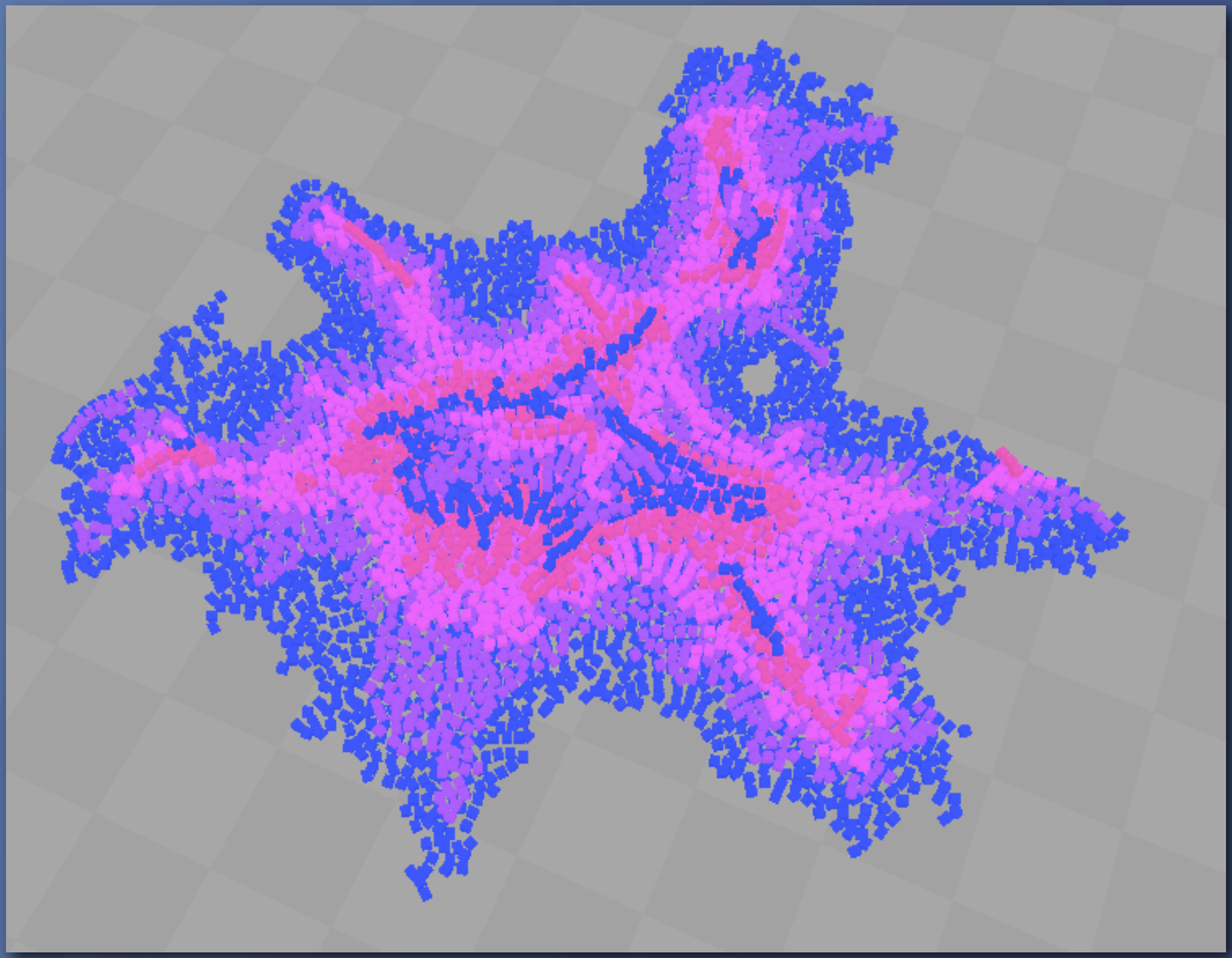




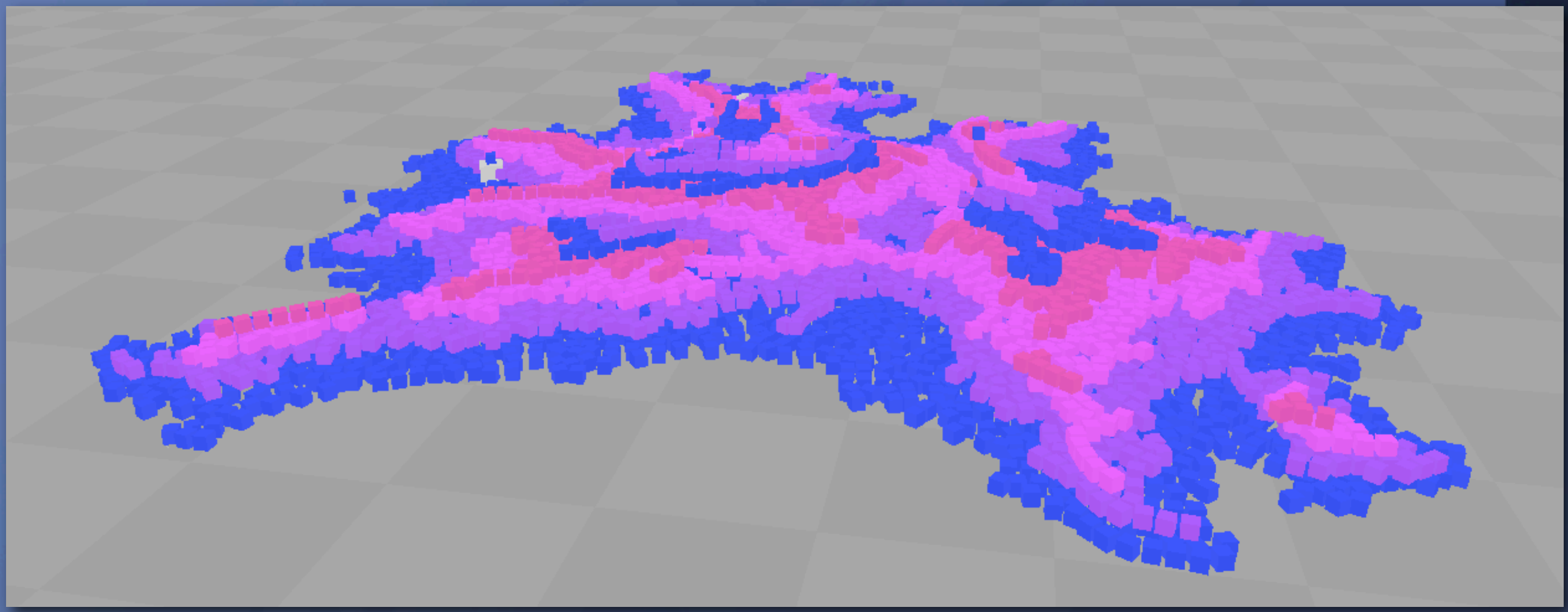

ts
cks
mp
d bricks: 0%
70 (568 fps)
53 (74 fps)







8000 bricks



8000 bricks

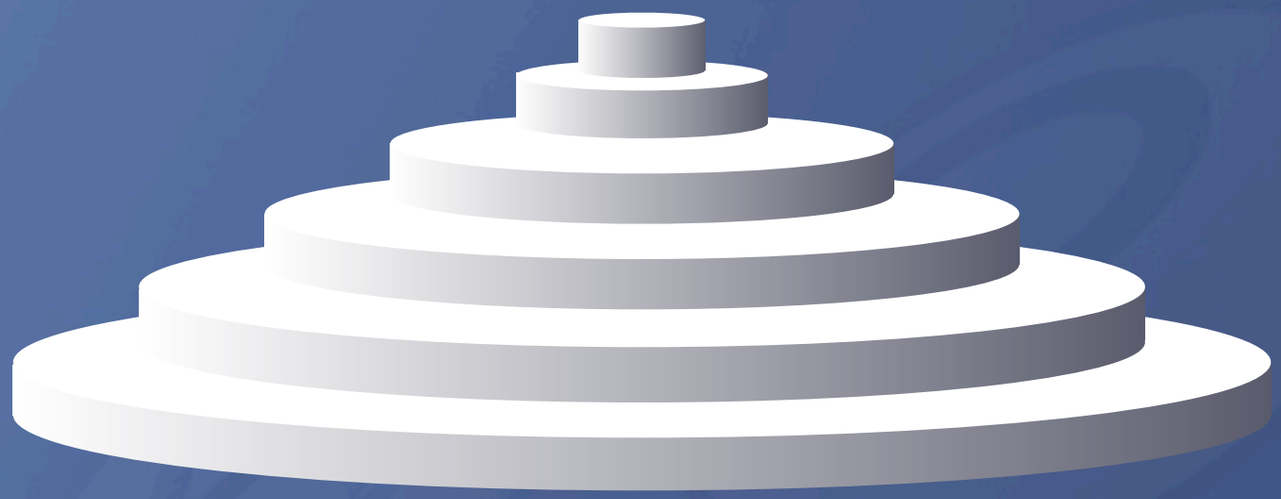
Stackers demo

part 1: central disk

part 2: central heap

Emergent construction site selection

- Forage for brick
- Select construction site
- Proceed as for fixed global construction target



Fixed global construction target

Emergent construction target

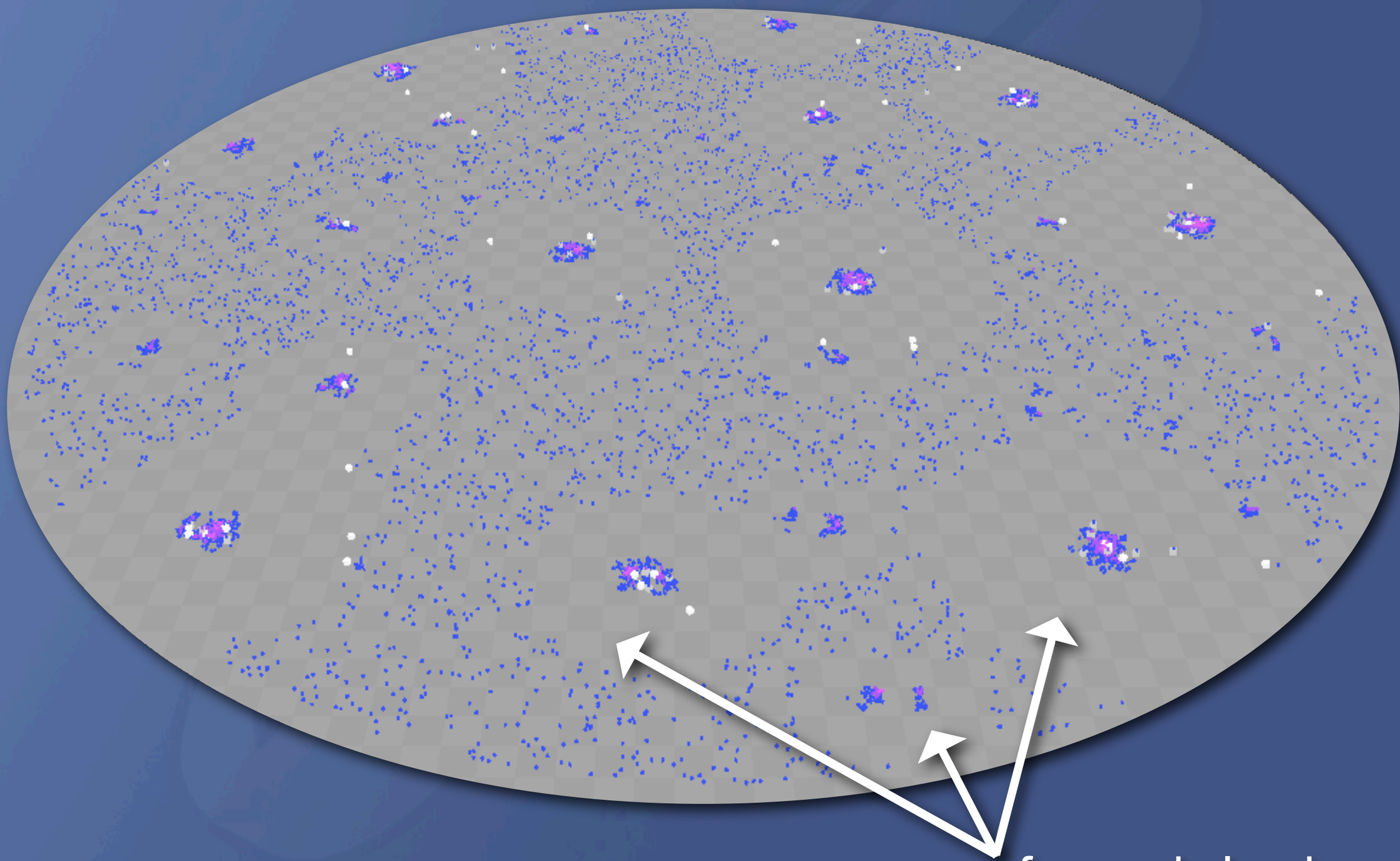
Self-reinforcement and recruitment

- Without additional goals:
  - many small towers
  - Bricks added/removed at same rate
- Use *score* to climb density gradient:
  - construction target must score higher than pick-up score
  - forage target must score lower than last drop-off score
- Generally bricks are moved from low to high density
  - Higher density attracts more agents
  - More agents lead to higher tower with more density

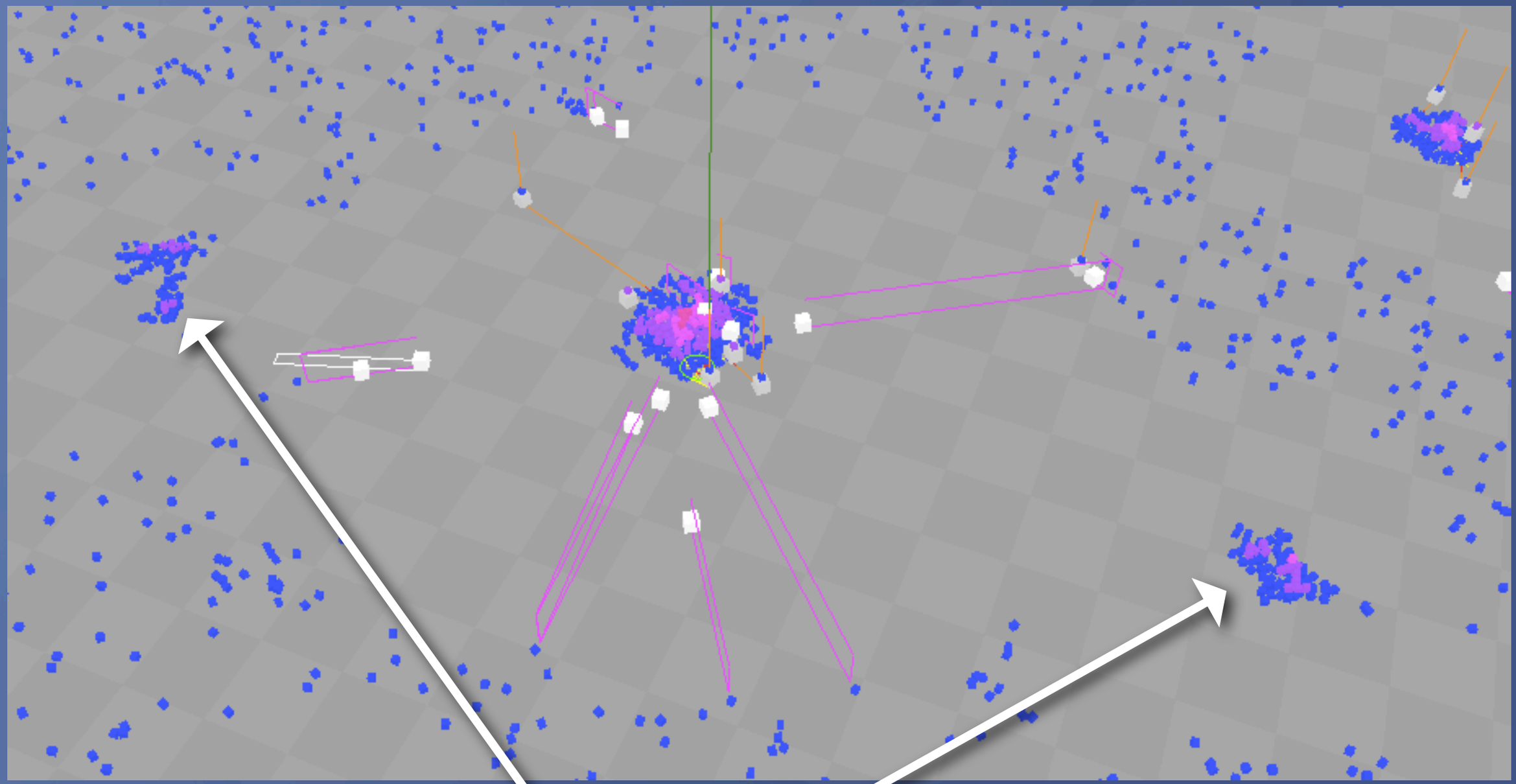
Termites: emergent pillar placement

Scott Turner, SUNY Syracuse, used with permission

Emergent construction sites

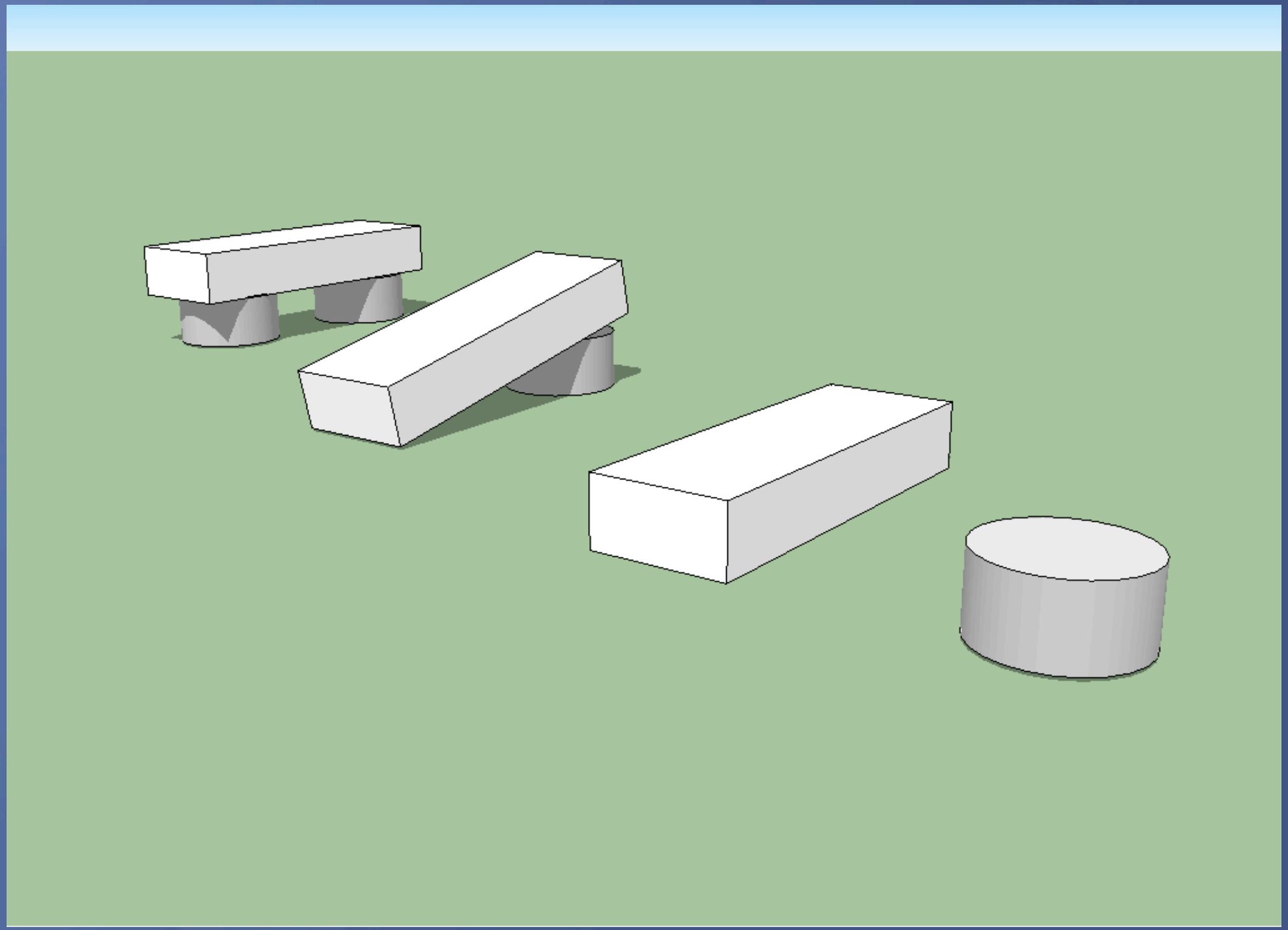


Emergent recruitment

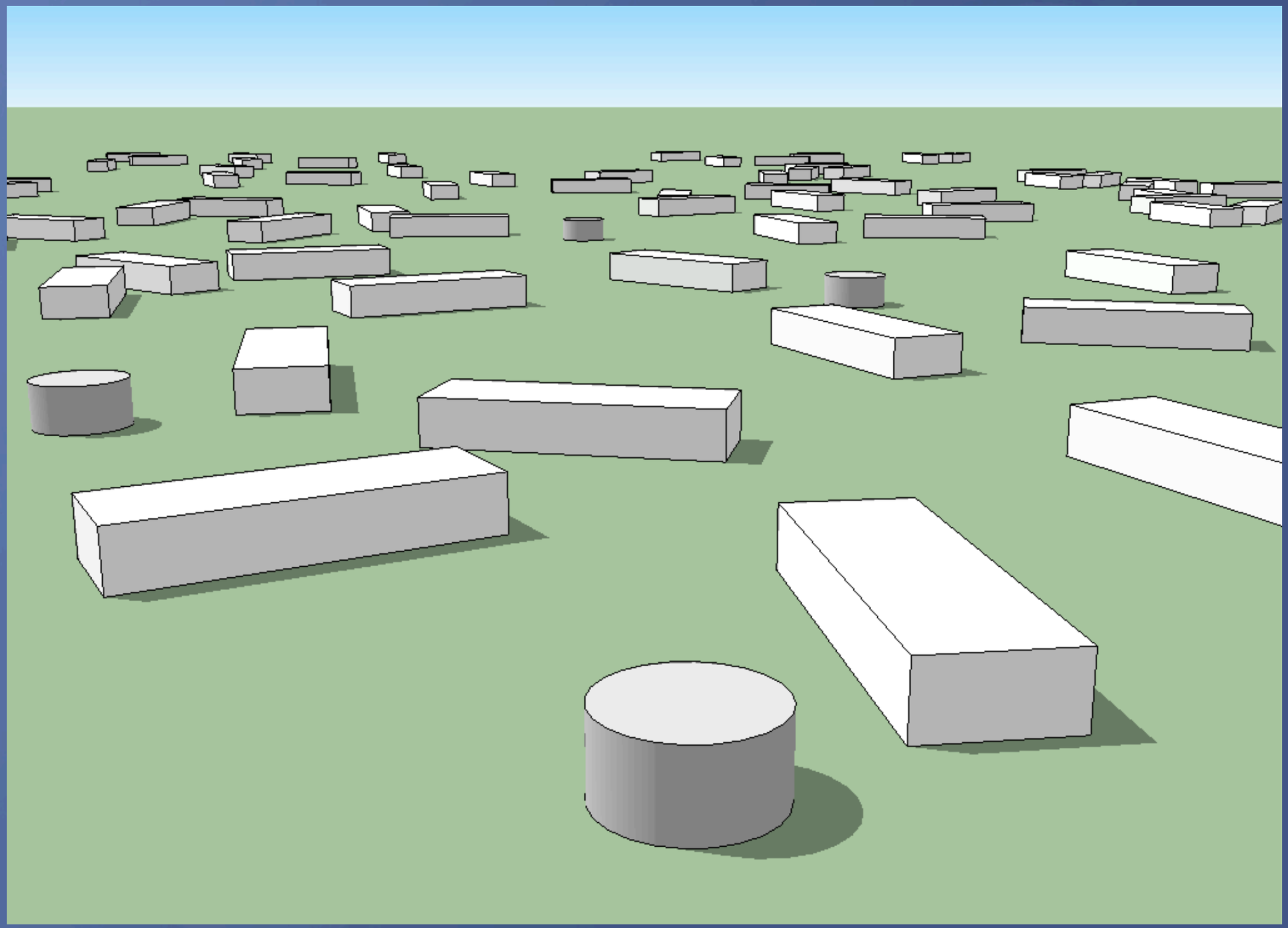


Stackers demo
part 3

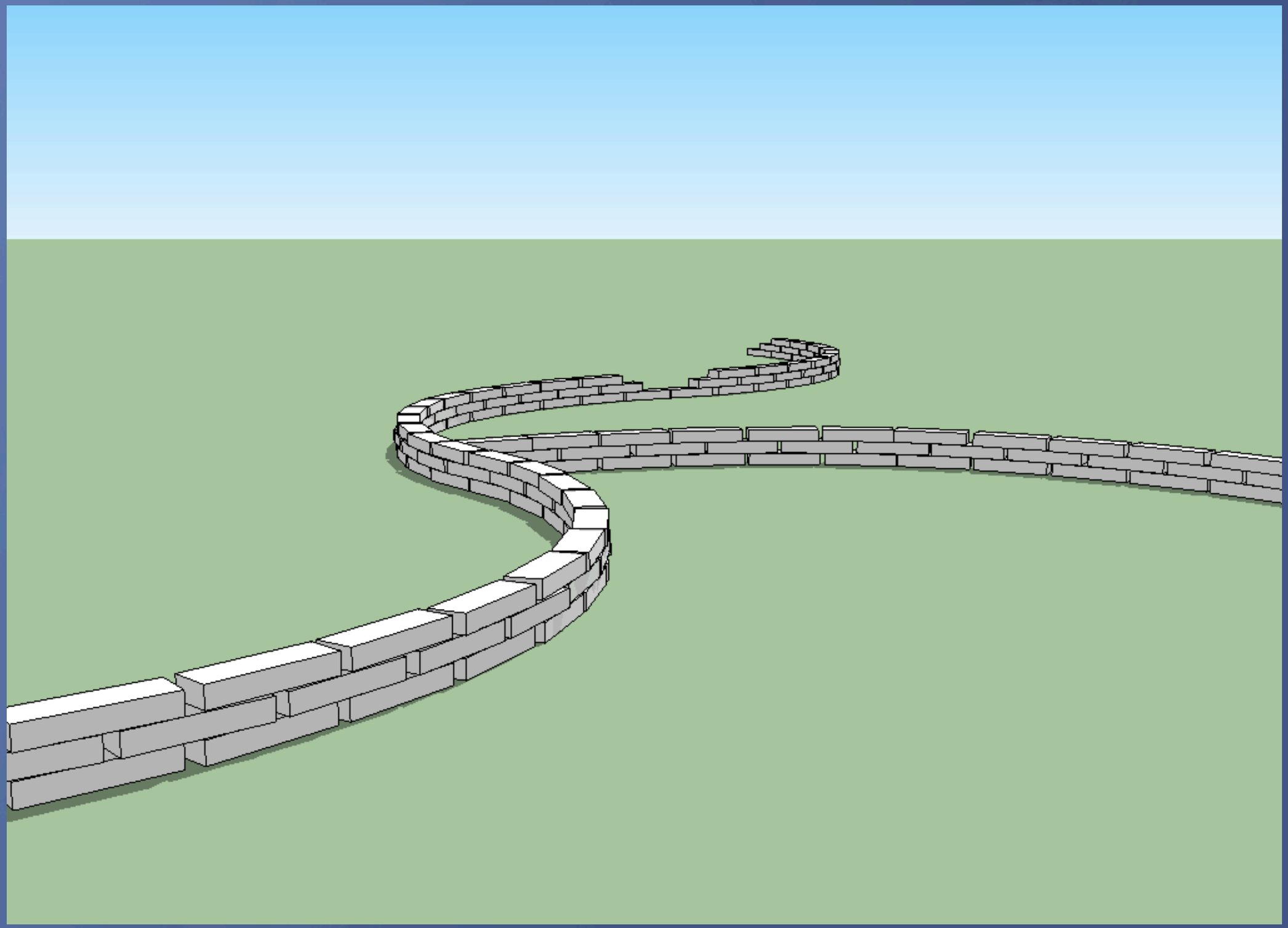
Future work:
emergent wall building



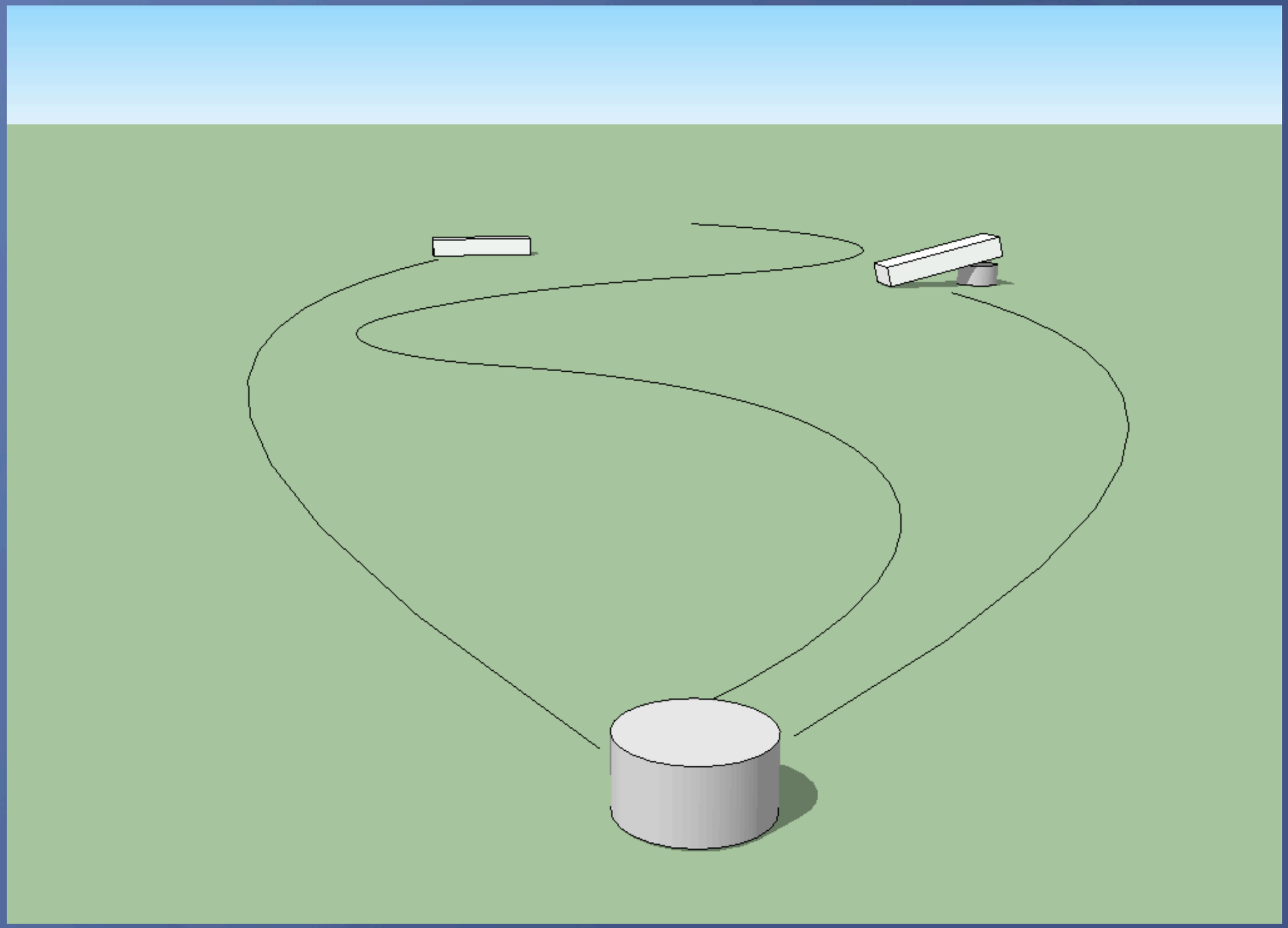
wall building 1



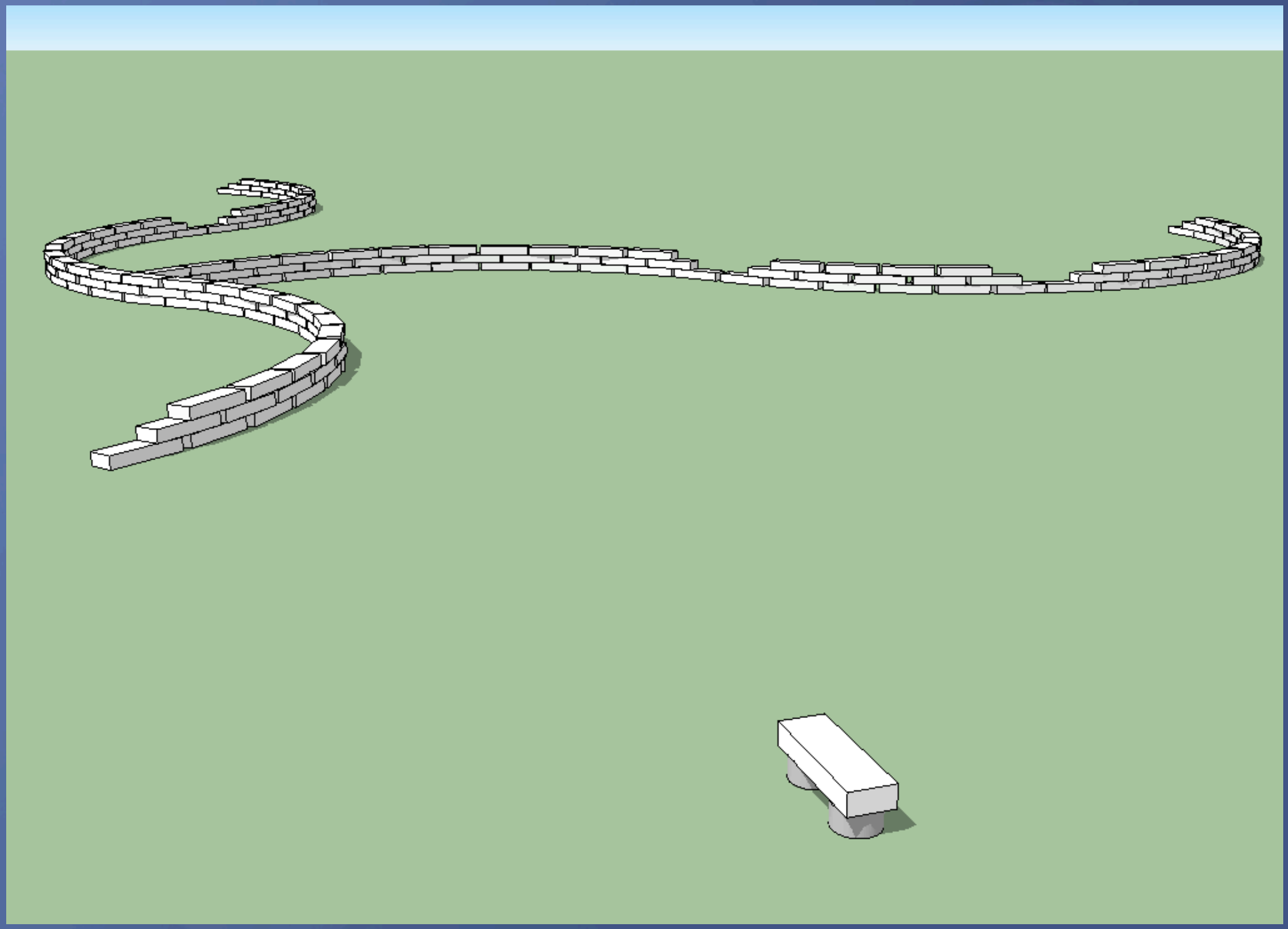
wall building 2



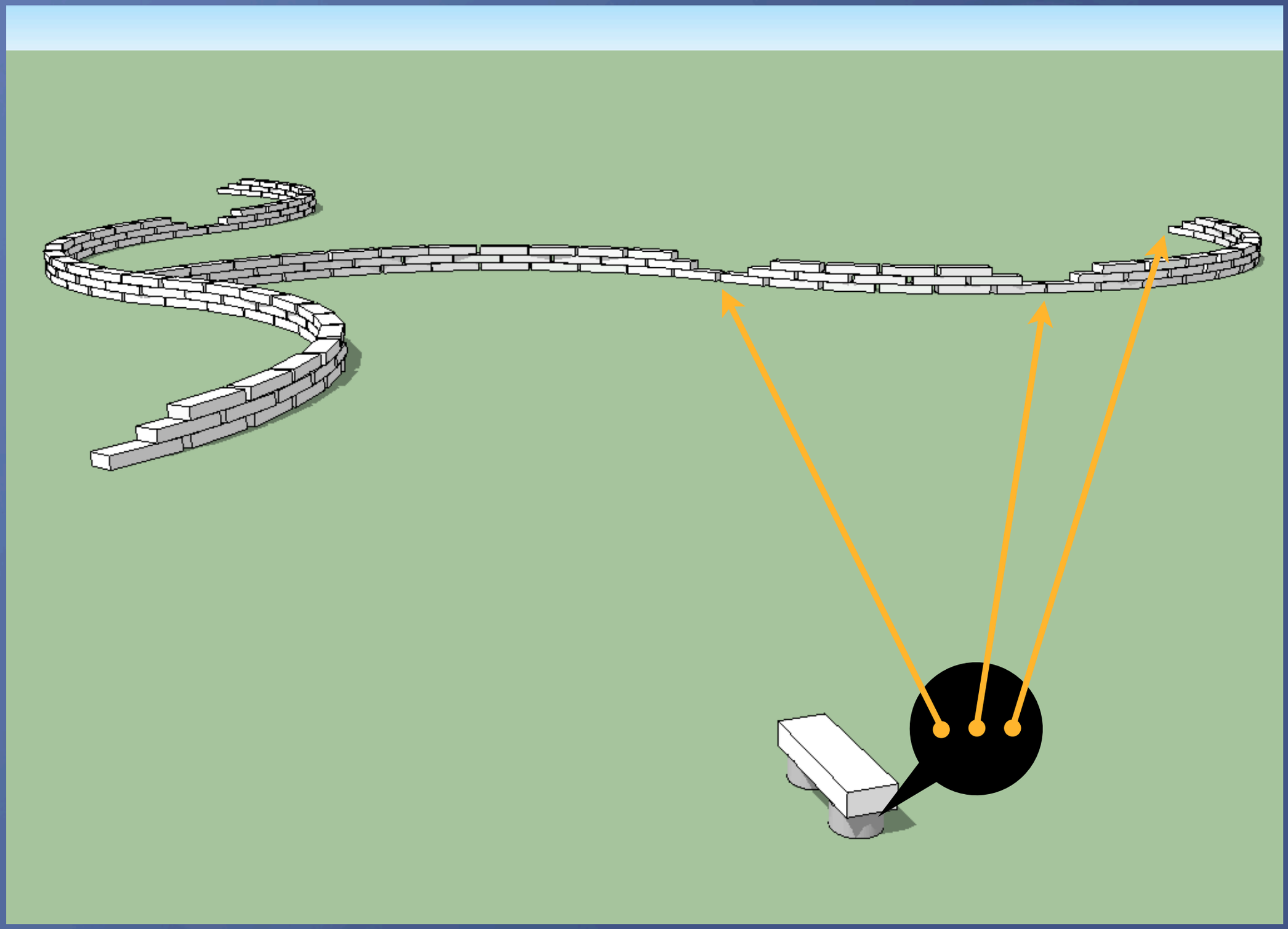
wall building 3



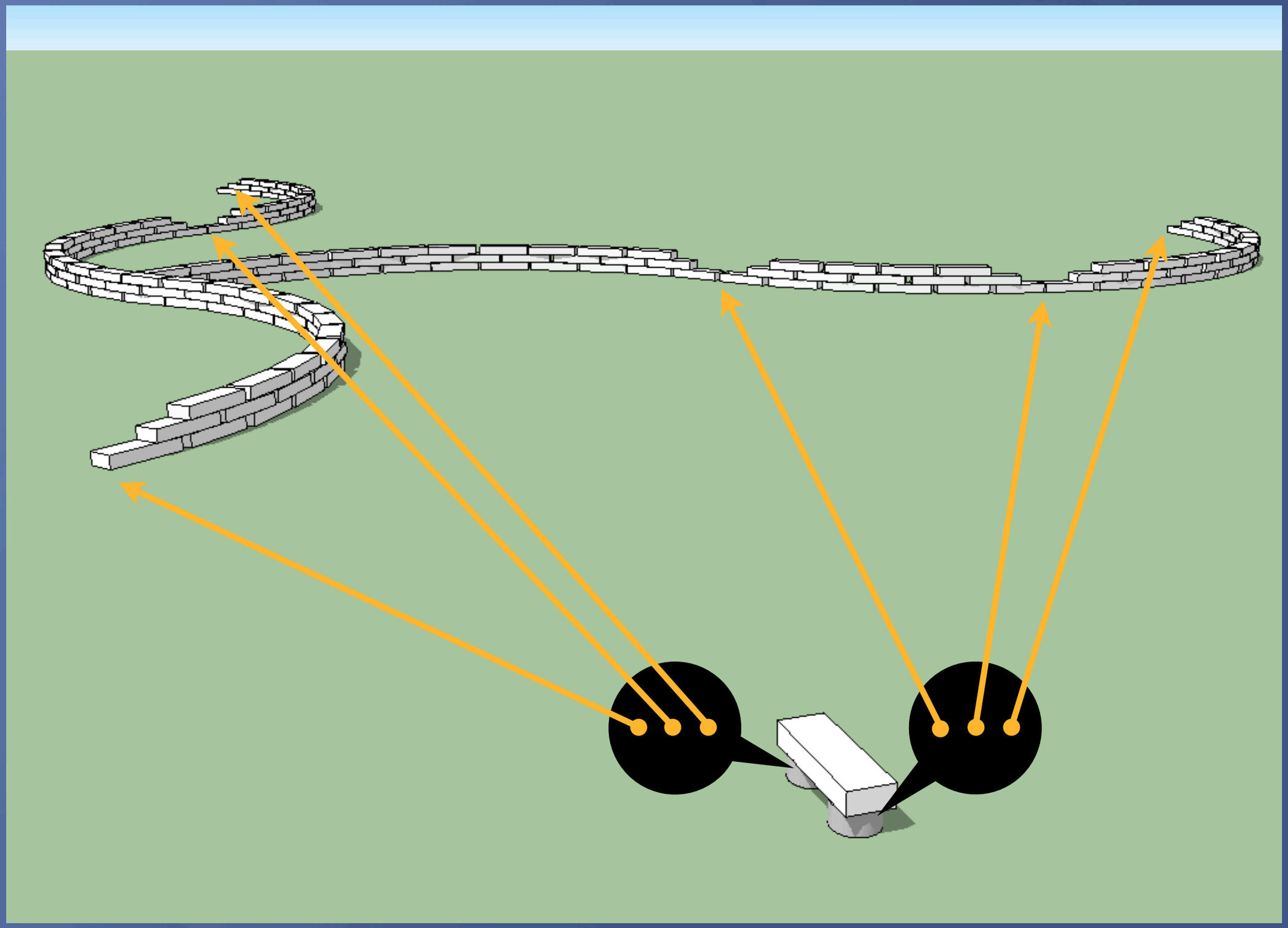
wall building 4



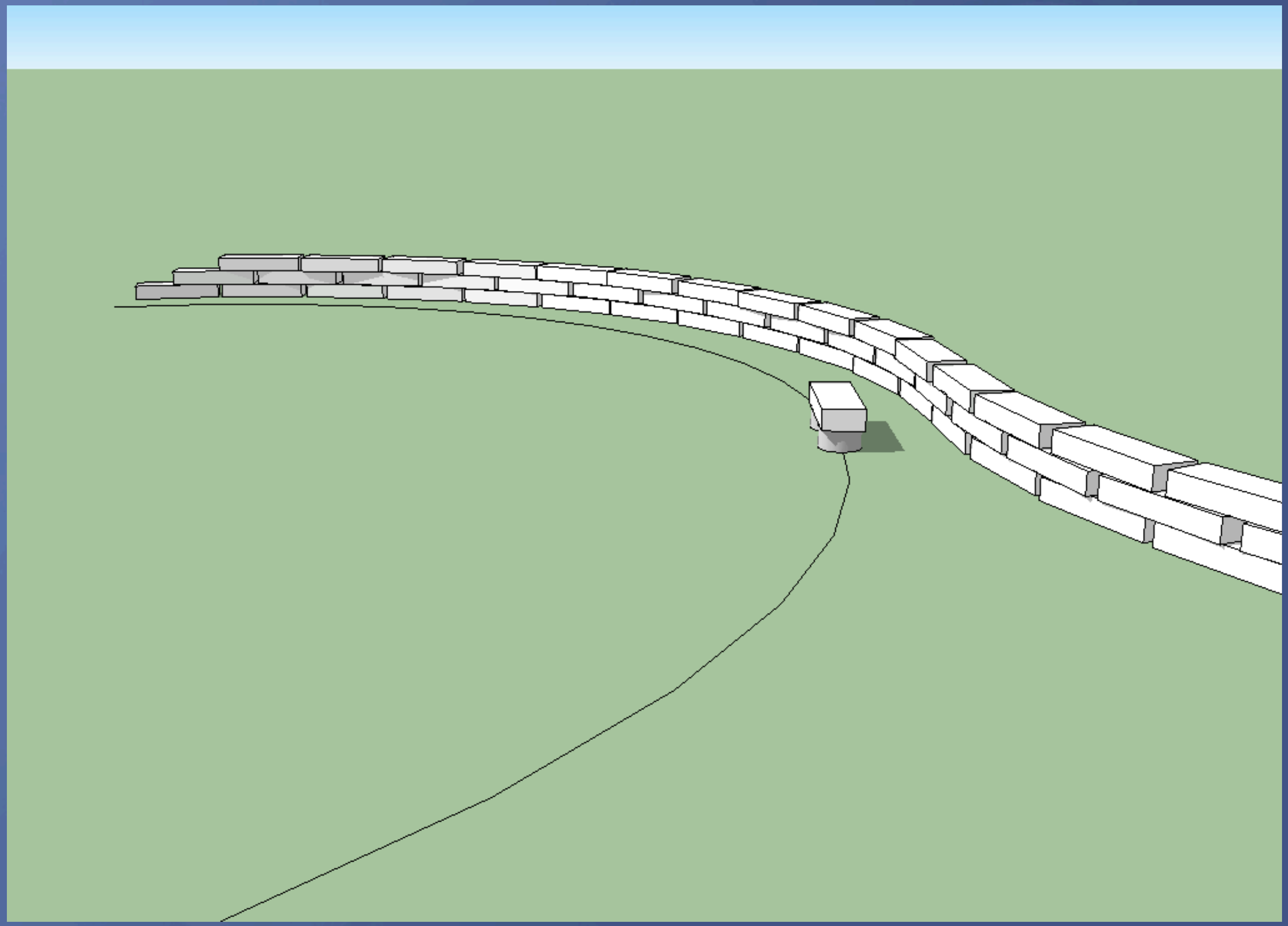
wall building 5



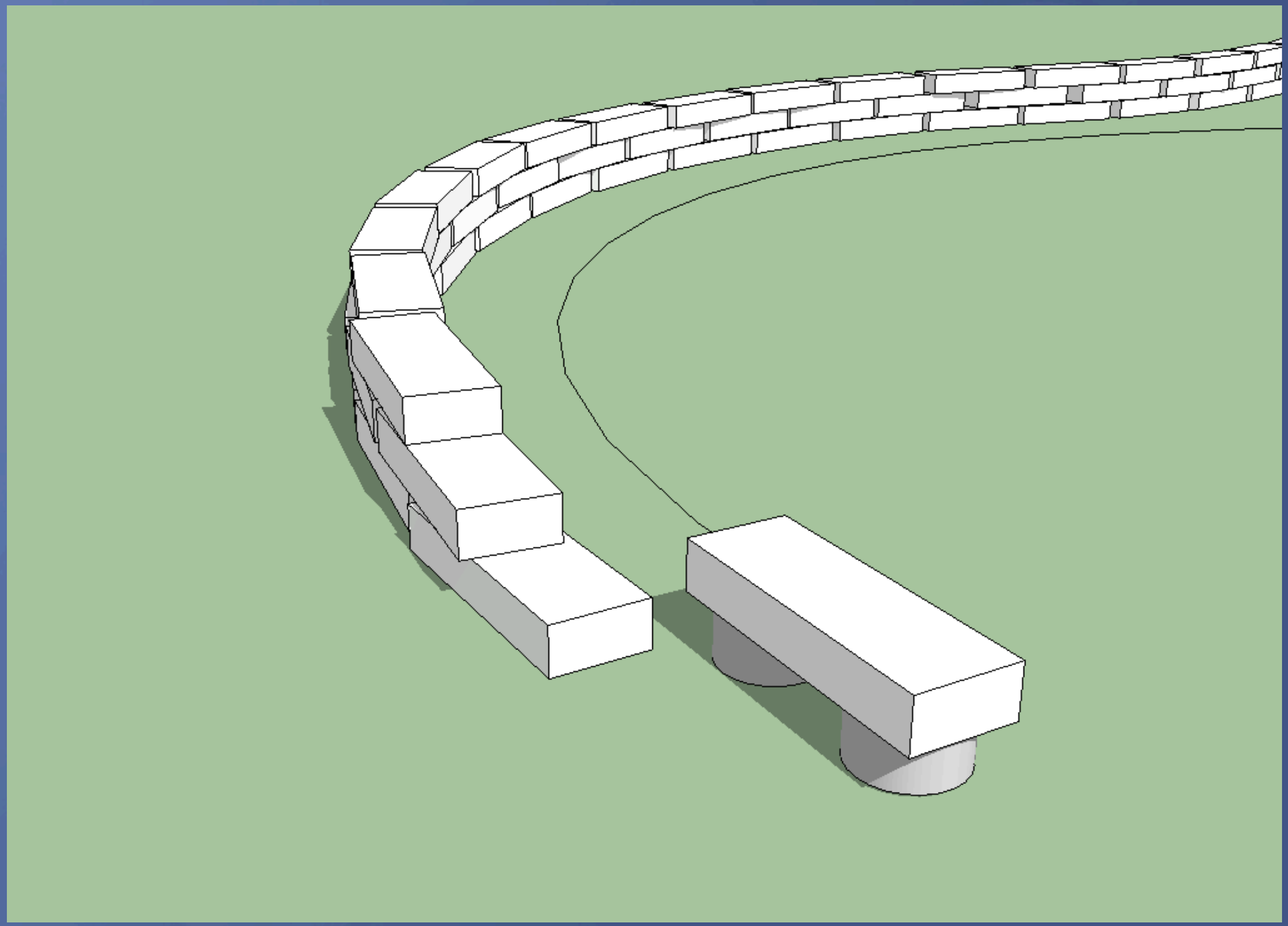
wall building 5



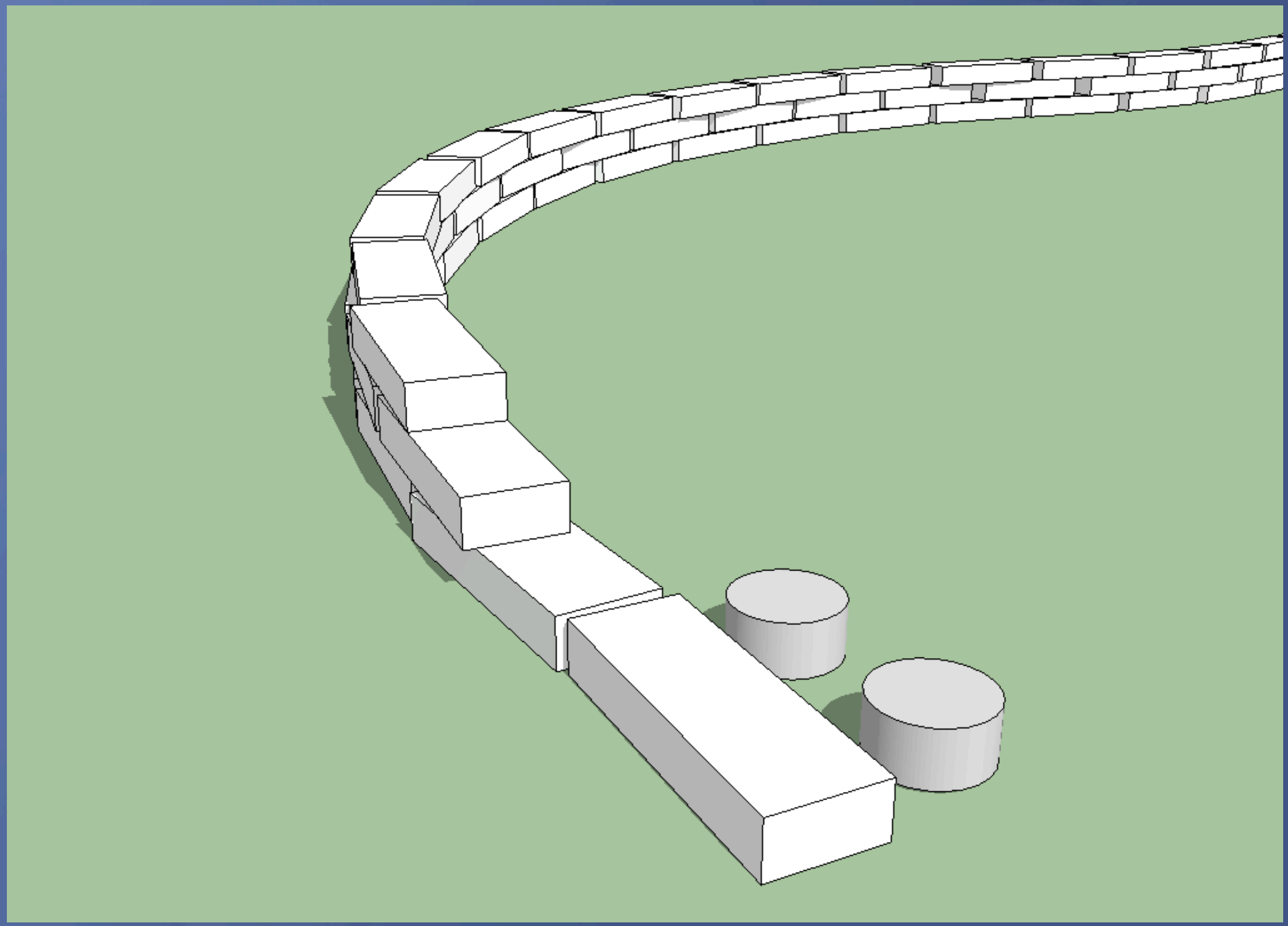
wall building 5



wall building 6



wall building 7



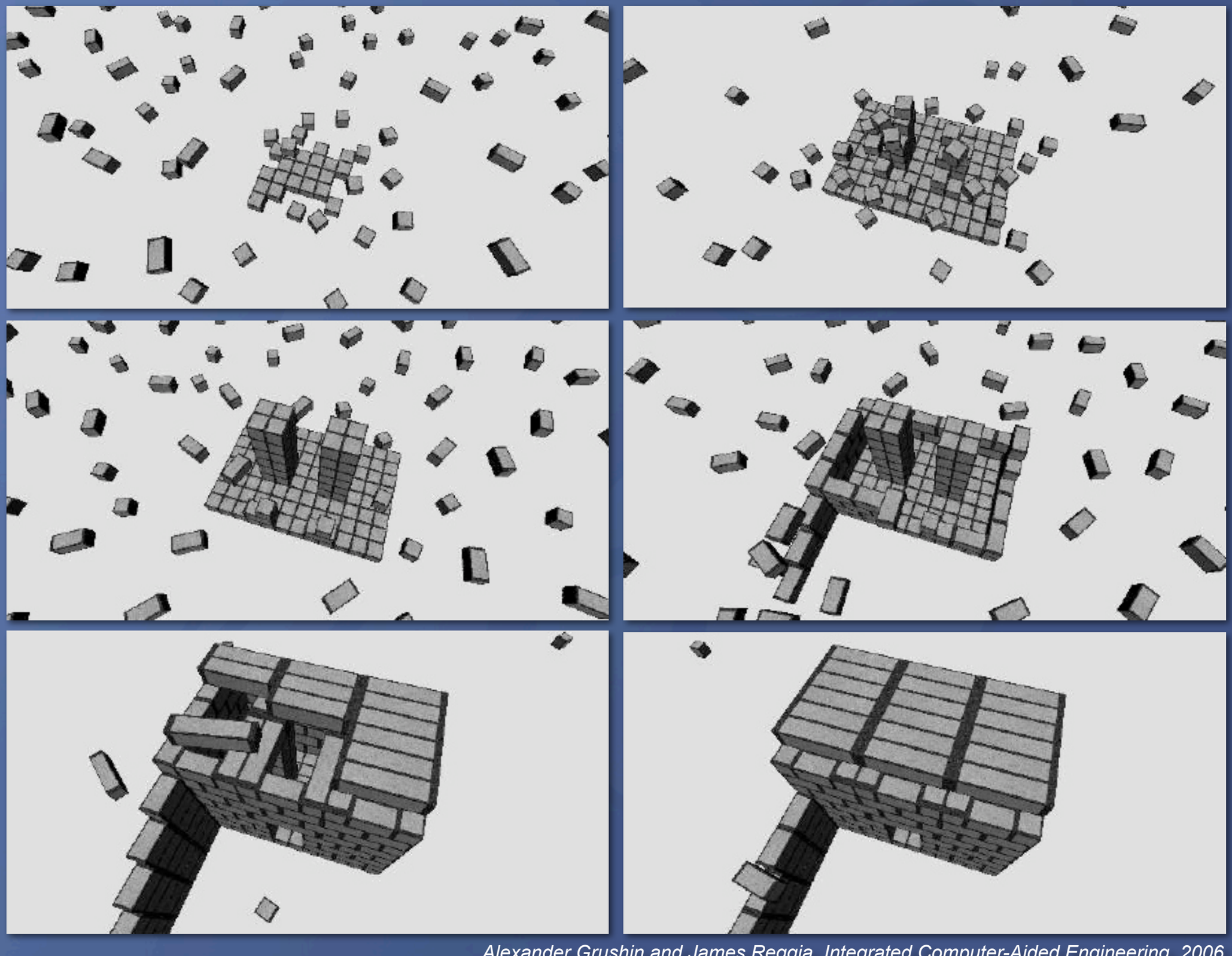
wall building 8

Future work:

ideas about construction styles

Sony Computer Entertainment US Research and Development
http://www.research.scea.com

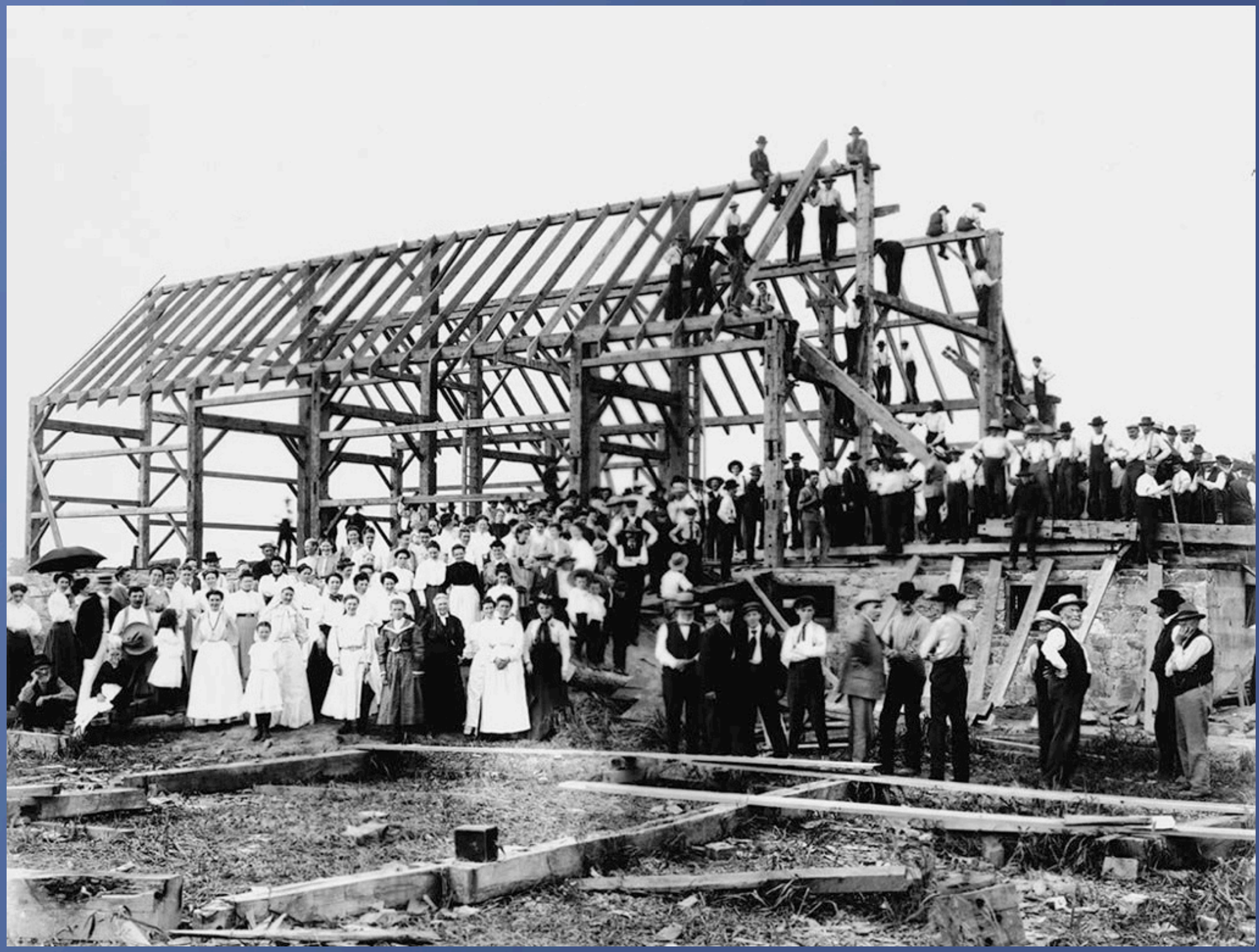
Stigmergic Self-Assembly of Prespecified Artificial Structures in a Constrained and Continuous Environment



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

Mesa Verde Cliff Dwellings

circa 1900, Washington University Archives



Barn raising near Toronto, Canada -- circa 1910 -- via Wikimedia Commons

modern construction of traditional English cottage -- ©2007 Ichthus Architects

circa 1950, Carlanna Lake Dam, Ketchikan Museums

circa 1915, trestle under construction, Snoqualmie Falls Lumber Company, by Clark Kinsey, U. Wash. Library

circa 1890, (re?)construction of stone footing, Mission B.C. Virtual Quilt

Thank you