Digression...

Autonomous Agents, Emergent Behaviour and Swarm Intelligence

Agent Based Modeling

- Computer simulation that represents individual entities in a dynamic social system.
- **Bottom-Up vs. Top-Down Approach**
- Agents represent heterogeneous and autonomous entities who interact with each other and/or their environment based on set rules, i.e. **decentralized decision-making**
- From these interactions, macro-scale behaviors may emerge (emergent behavior)

Why Agent Based Modeling?

- The whole greater than the sum of its parts.
- The need of analyzing the complexity of systems with less mechanistic and **more organic approaches** has emerged in different fields.
- Complexity theory shows that even if we were capable to have a **complete understanding of the factors affecting individual action**, this would be still **insufficient to predict group behavior**.

Agents

Generally, an agent has 4 features (Woolridge-Jennings, 1995)

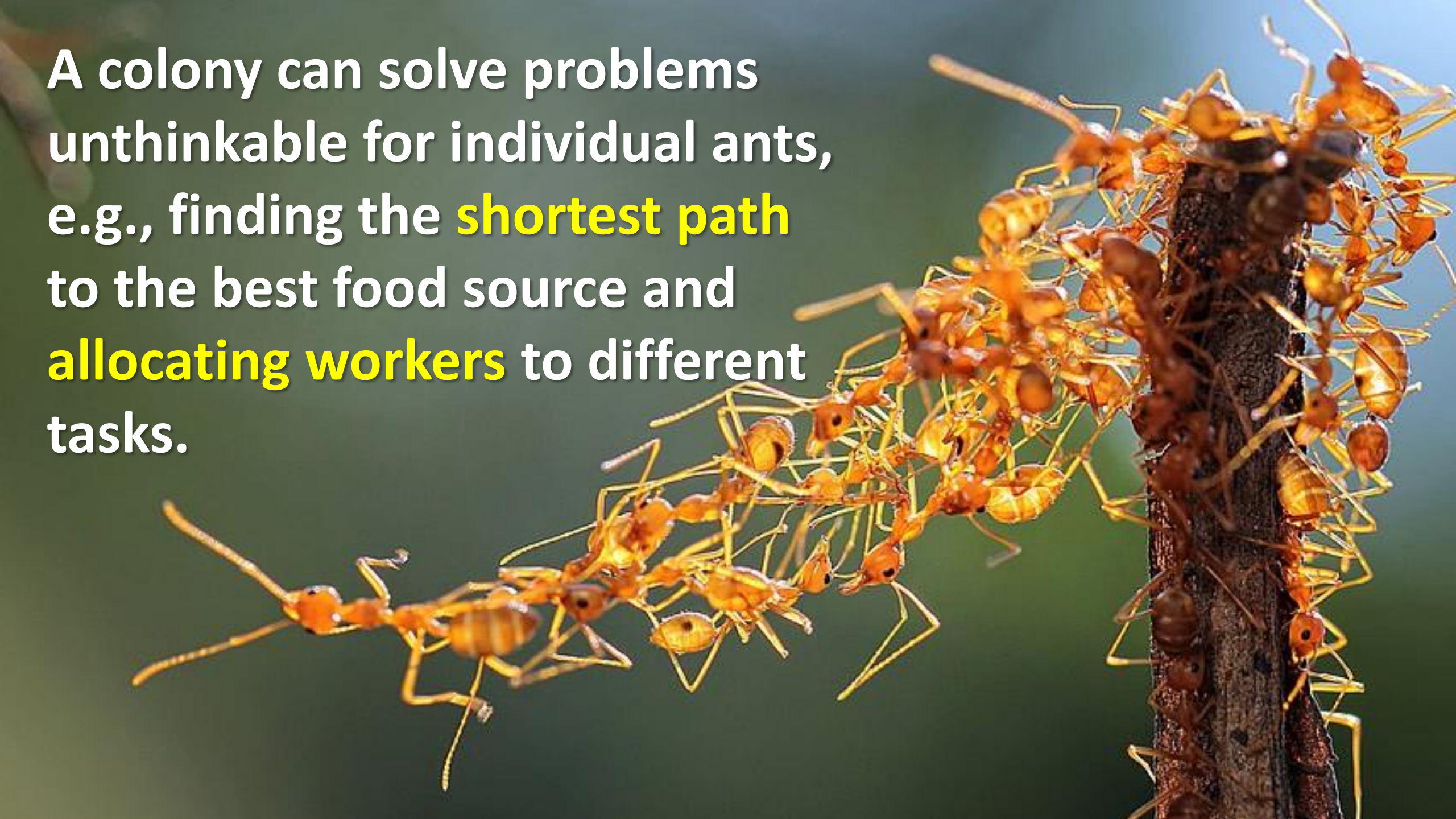
1. **Autonomy:** Each agent acts independently and makes its own decisions. (some randomness may be involved in its decision making)
2. **Social Ability:** Each agent can interact with other agents.
3. **Reactivity:** Each agent will react appropriately to stimuli.
4. **Proactivity:** Each agent pursues its own goals and acts in its own self-interest.

Ants are not smart.

Ants are not clever little engineers, architects, or warriors…

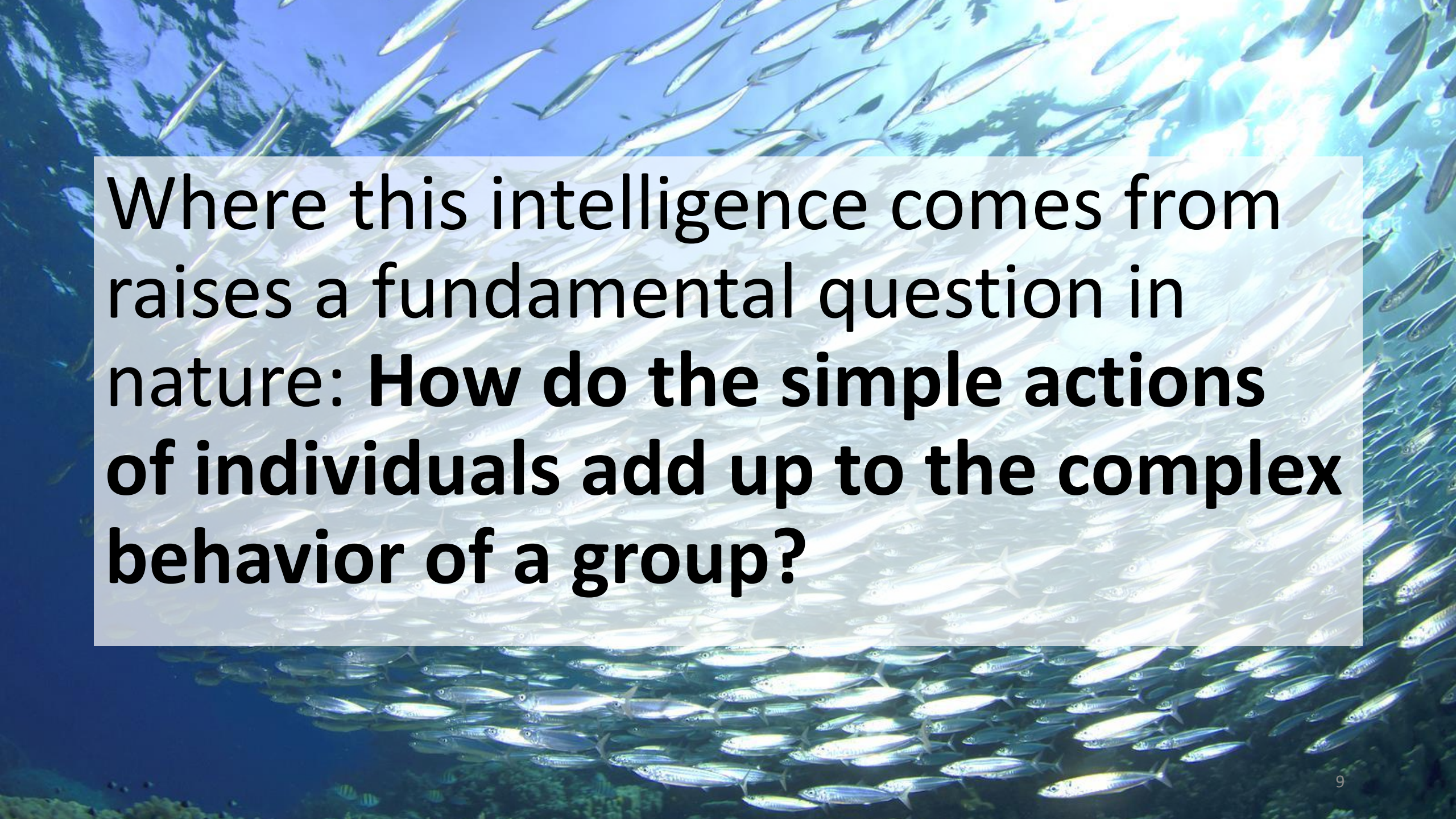
at least not as individuals.


Ants aren't smart,
but colonies are


A colony can solve problems unthinkable for individual ants, e.g., finding the shortest path to the best food source and allocating workers to different tasks.

Swarm Intelligence

As individuals, ants might be tiny dummies, but as colonies they respond quickly and effectively to their environment. They do it with something called **swarm intelligence**.



Where this intelligence comes from raises a fundamental question in nature: **How do the simple actions of individuals add up to the complex behavior of a group?**

Ants are not smart…

One key to an ant colony, for example, is no one is in charge.

Even with half a million ants, a colony functions just fine with no management at all…

It relies instead upon countless interactions between individuals, each of which is following simple rules of thumb.

The system is self-organizing.

Before they leave the nest each day, foragers wait for early morning patrollers to return. As patrollers enter the nest, they touch antennae briefly with foragers.

When a forager has contact with a patroller, it's a stimulus for the forager to go out, but the forager needs several contacts no more than ten seconds apart before it will go out.

Foragers use the rate of their encounters with patrollers to tell if it's safe to go out.

Once the ants start foraging and bringing back food, other ants join the effort, depending on the rate at which they encounter returning foragers.

A forager won't come back until it finds something. The less food there is, the longer it takes the forager to find it and get back. The more food there is, the faster it comes back.

No ant sees the big picture. No one particular ant decides whether it's a good day to forage. The collective decides.

Emergent Behavior

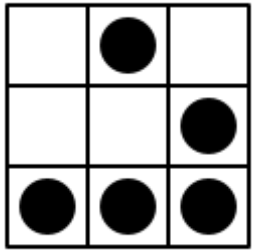
- 1970’s John Conway’s “Game of Life”
- 1970’s Schelling’s Segregation Model
- 1980’s Reynold’s Boids

→ Agent-Based Modeling

Cellular Automata (CA)

- An early predecessor to artificial swarms, emergent behavior, and Agent-Based Modeling
- Cellular Automata are spatially and temporally discrete
  - composed of a finite set of homogeneous and simple units called “cells”
  - they evolve in parallel at discrete time steps
- At each instance in time, the cells instantiate one of a finite set of states
- Interaction is usually limited to ‘cells’ within an immediate neighborhood

Conway's Game of Life



1. Any live cell with fewer than two live neighbors dies, as if by loneliness.
2. Any live cell with more than three live neighbors dies, as if by overcrowding.
3. Any live cell with two or three live neighbors lives, unchanged, to the next generation.
4. Any dead cell with exactly three live neighbors comes to life.

Conway's Game of Life

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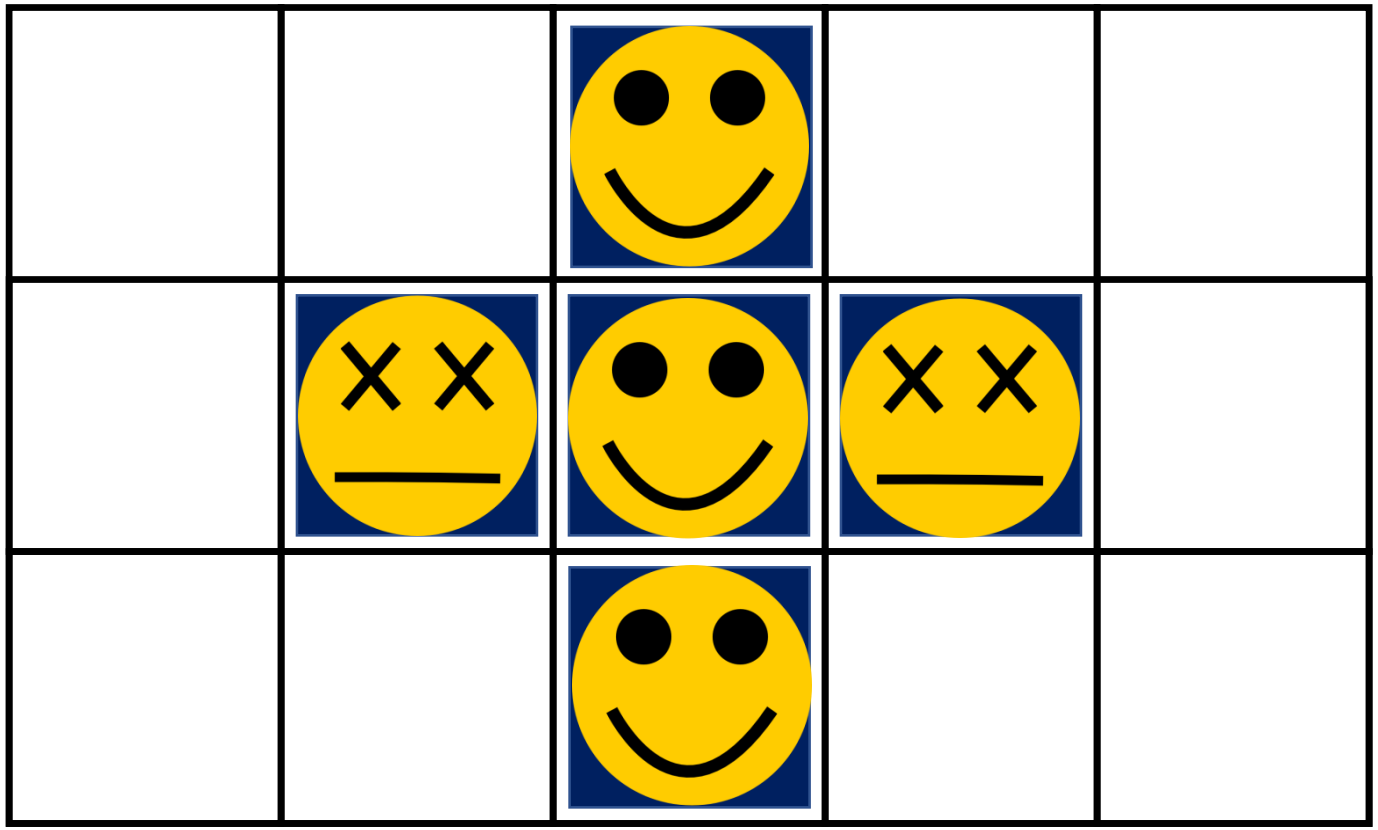

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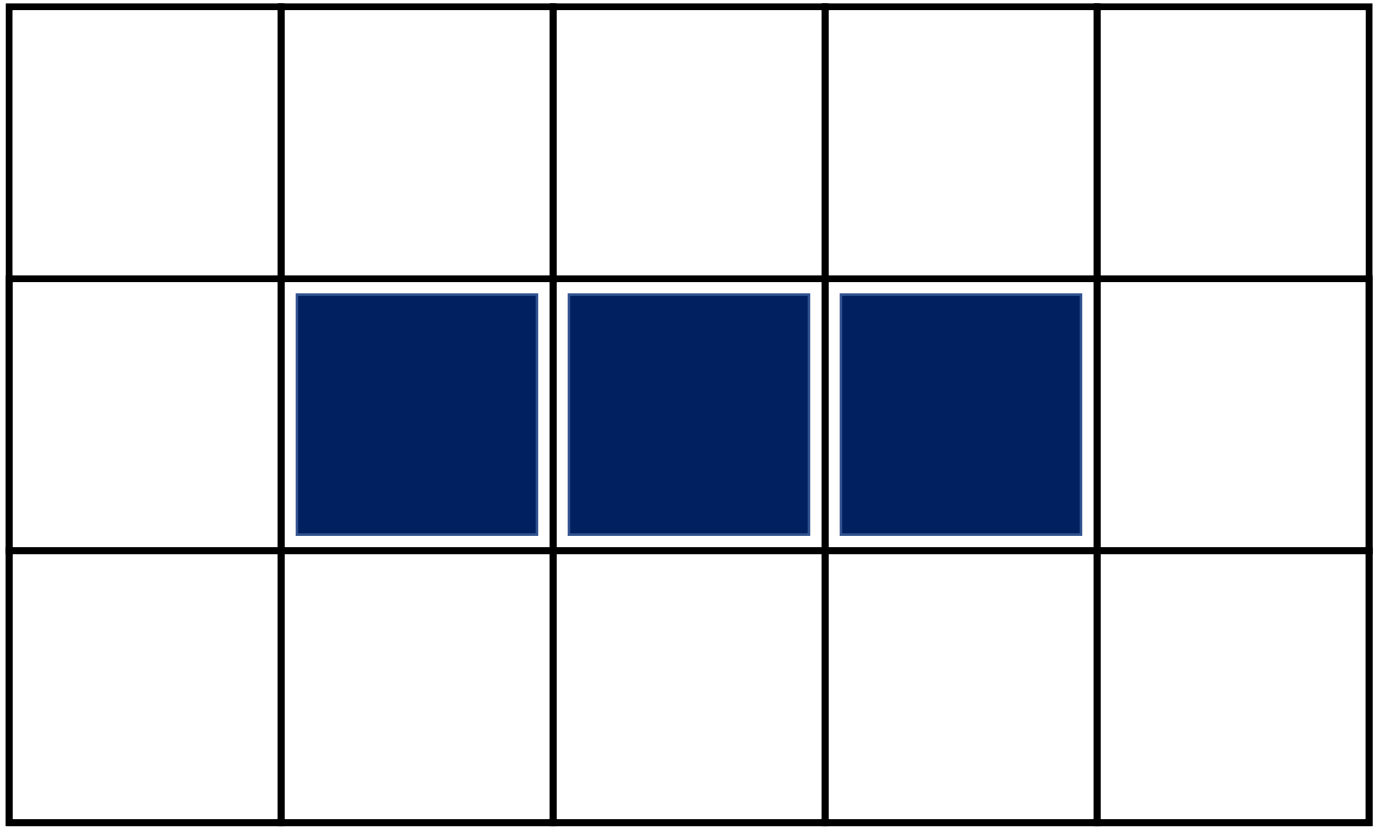

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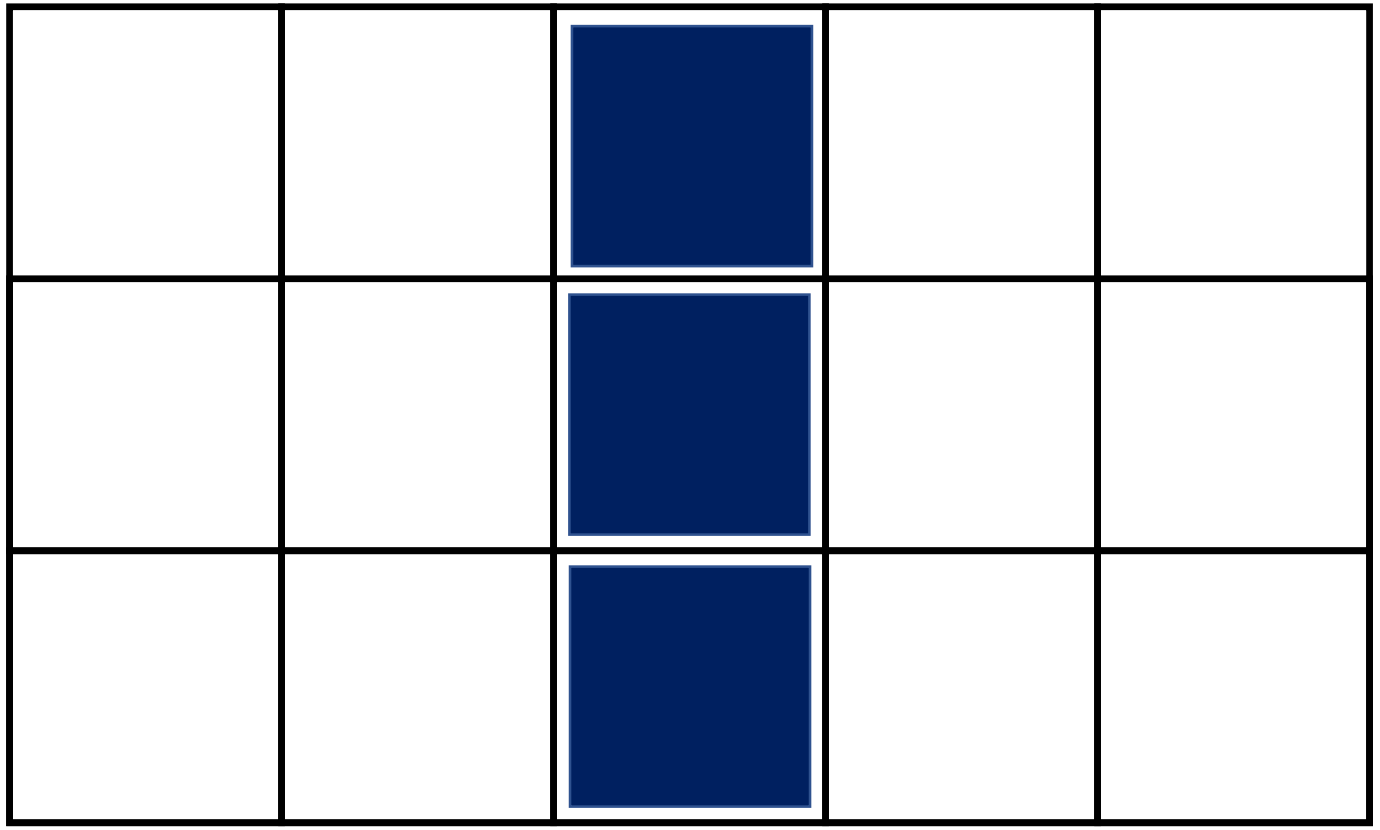


Cellular Automata Examples

Downloadable game:

http://golly.sourceforge.net/

Video example:

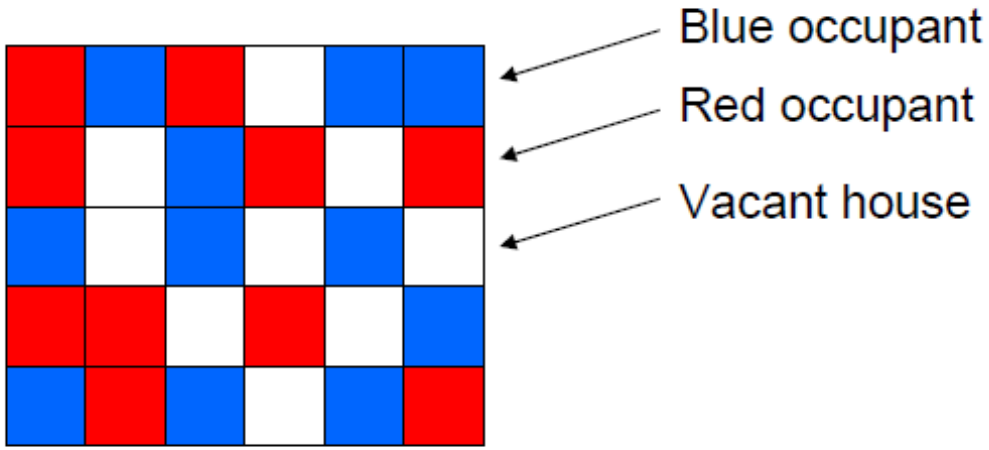
https://www.youtube.com/watch?v=C2vgICfQawE

Schelling's Segregation Model

- Why do many urban neighborhoods consist mostly of one race or ethnicity?
  - **Widespread racism?**
  - **Something less extreme?**
- In 1971, economist Thomas Schelling (Nobel Prize 2005) proposed an ABM to understand urban segregation

Schelling's Model

- A city has two ethnicities: Reds & Blues
- Each cell on a rectangular grid is a house
- Each house has a Red occupant, a Blue occupant, or is vacant (white)



Schelling's Model: Rules

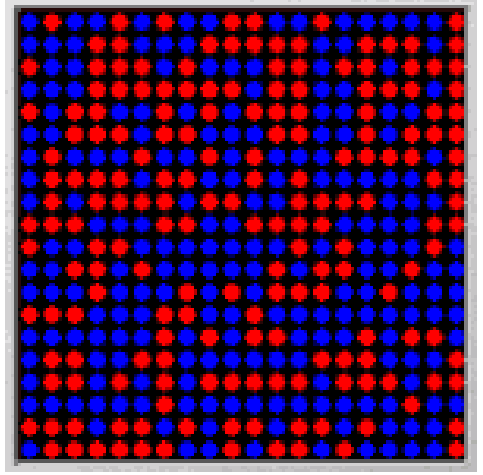
- Each person (agent) is *ethnocentric* – and is "happy" if 50% or more of its neighbors are its own color
- Unhappy agents are allowed to switch places

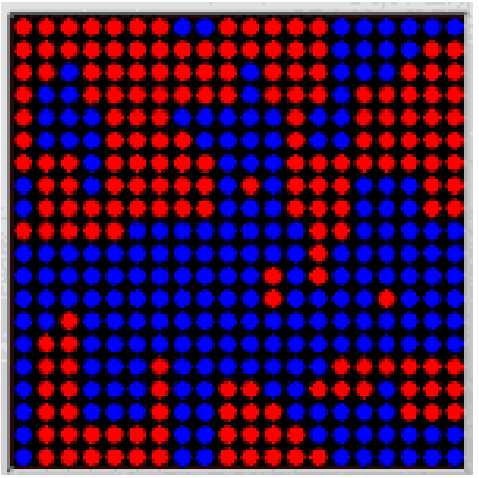
Schelling Model

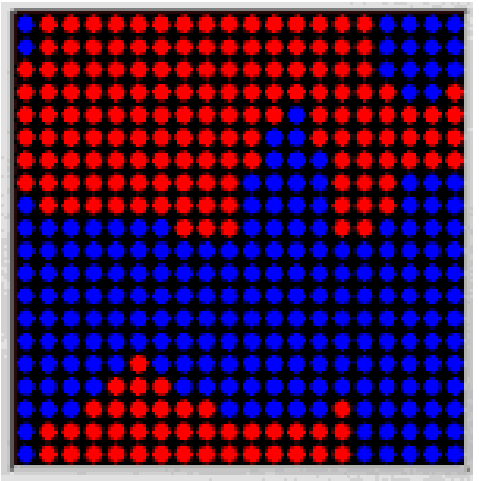
In the first frame blues and reds are randomly distributed.

But they do not stay that way for long -- unhappy agents move.

Very quickly the reds and blues gravitate to their own neighborhood, and soon the segregation is complete: reds and blues live in two distinct districts



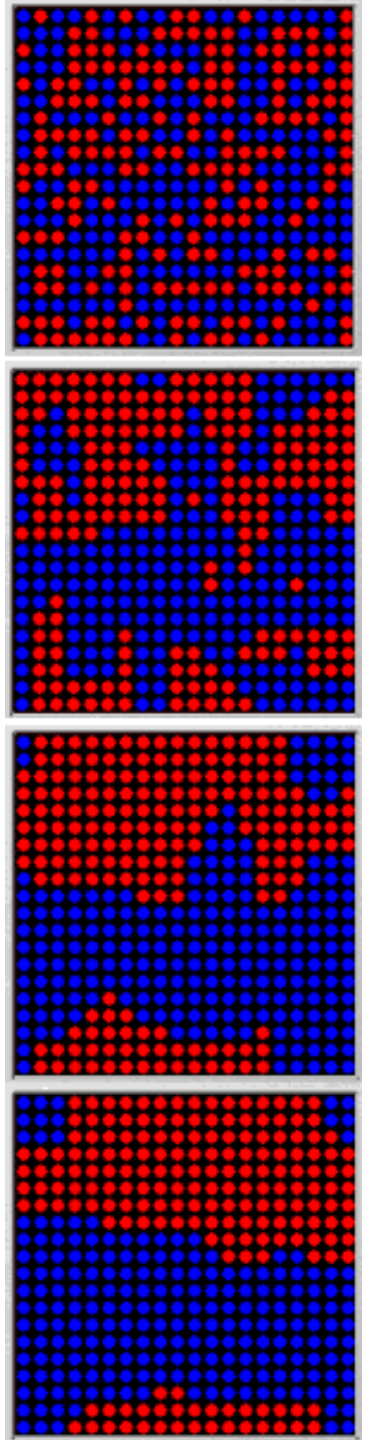




Schelling Model

"These people would all be perfectly happy in an integrated neighborhood, half red, half blue.

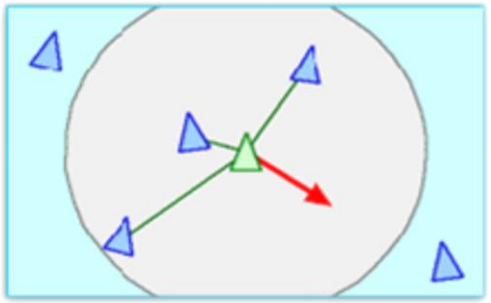
If they were real, they might well swear that they valued diversity. The realization that their individual preferences lead to a collective outcome indistinguishable from thoroughgoing racism might surprise them…"



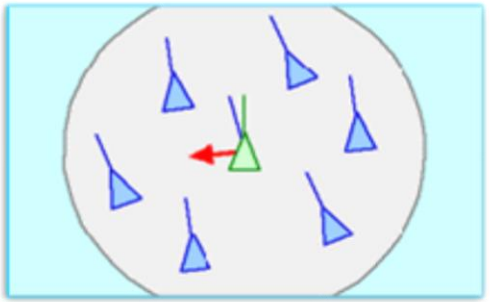
Boids

In 1986, Craig Reynolds proposed the Boids model to describe flocking behavior.

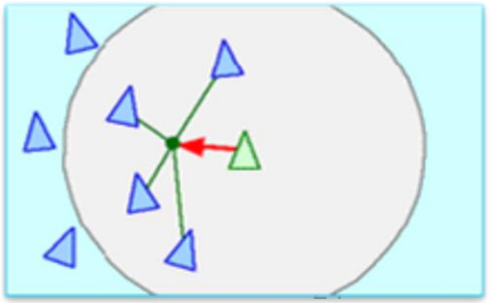
1. **separation**: steer to avoid crowding local flockmates



2. **alignment**: steer towards the average heading of local flockmates



3. **cohesion**: steer to move toward the average position of local flockmates



some Boids examples:

https://www.youtube.com/watch?v=QbUPfMXXQIY

https://www.youtube.com/watch?v=9gTjJxgBH5U

https://www.youtube.com/watch?v=DAL218HEsfg

https://www.youtube.com/watch?v=g0LwS4ysGbE

Agent Based Modeling Concept

- Modeler constructs a virtual world populated by different types of agents.
- Modeler determines initial world conditions
- Modeler then *steps back* to observe how the world develops over time without intervention
- World events are driven by agent interactions.

Besides these examples, who has seen ABM in action?

Conjecture = Everyone Has!

http://www.massivesoftware.com/gallery.html

Resident Evil:
Extinction

I,Robot

Fellowship of the Ring
Two Towers
Return of the King

X-Men:
Last Stand

Harry Potter:
Order of the Phoenix

300

King Kong

Elektra

Pirates of the Caribbean:
World's End

Eragon

Talladega Nights:
The Ballad of Ricky Bobby

One Night
With The King

Also commercials…

Carlton

https://vimeo.com/38210543

Corona

Playstation 2

http://www.massivesoftware.com/gallery.html

Applications of ABM

- Social Sciences
  - Communications in social networks
  - Spread of ideas and opinions
  - Economics of supply & demand
- Life Sciences
  - Spread of infectious diseases
  - Swarming / flocking behavior of animals
  - Interaction of cells
- Physical Sciences
  - Model the motion of gas particles
  - Model erosion and formation of geographic structures
- Computer Science
  - Make a realistic-looking army of orcs

Netlogo

Please check out the site:

http://ccl.northwestern.edu/netlogo/

ABM Summary

- **Agent based models consist of dynamically interacting rule-based agents.**
  - Adaptation to environmental conditions
  - Social communication with other agents
  - Goal-directed learning
  - Autonomy (self-activation and self-determinism based on private internal processes)
- **These interactions can create complexity like that which is seen in the real world.**