# Chapter 1: Introduction to Swarm Intelligence

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# A Bit About Social Insects

- Ants, bees, wasps, termites…
- Each individual operates on their own agenda → colony achieves organized complex behavior
- Workers specialize in a set of tasks
  - There are even *polymorphic* species!
- Exhibit decentralized problem-solving (No supervisor present)

# An example

# The Big Question:
# How are individual behaviors connected with collective performance?

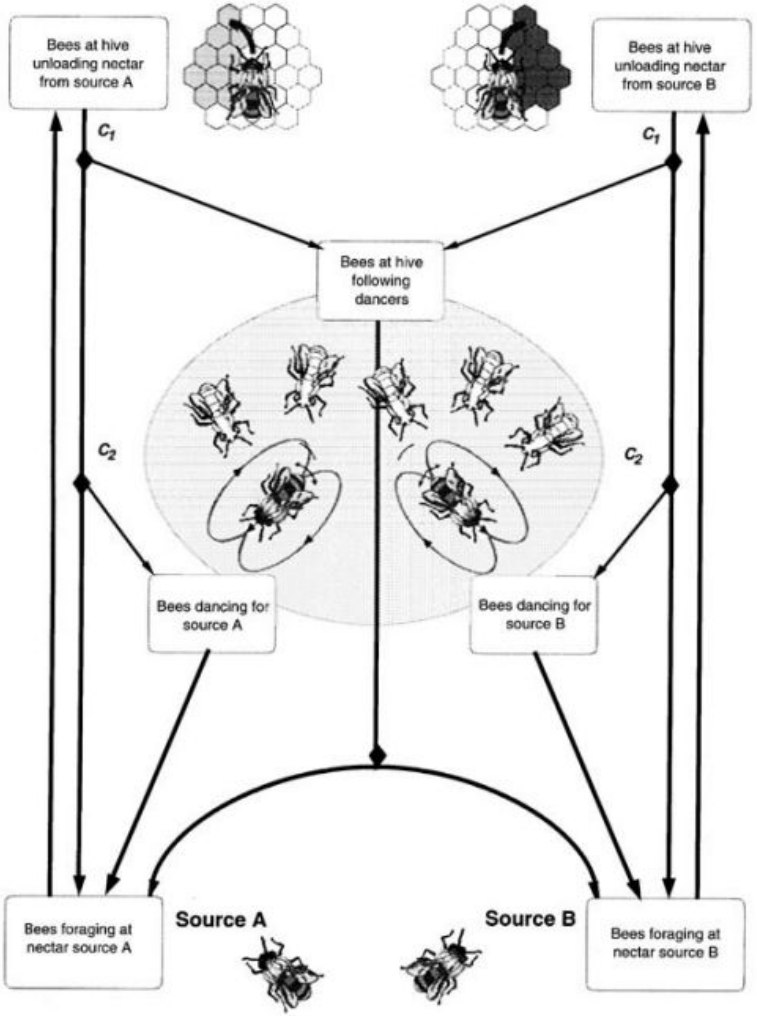
Collective behaviors are *self-organized*

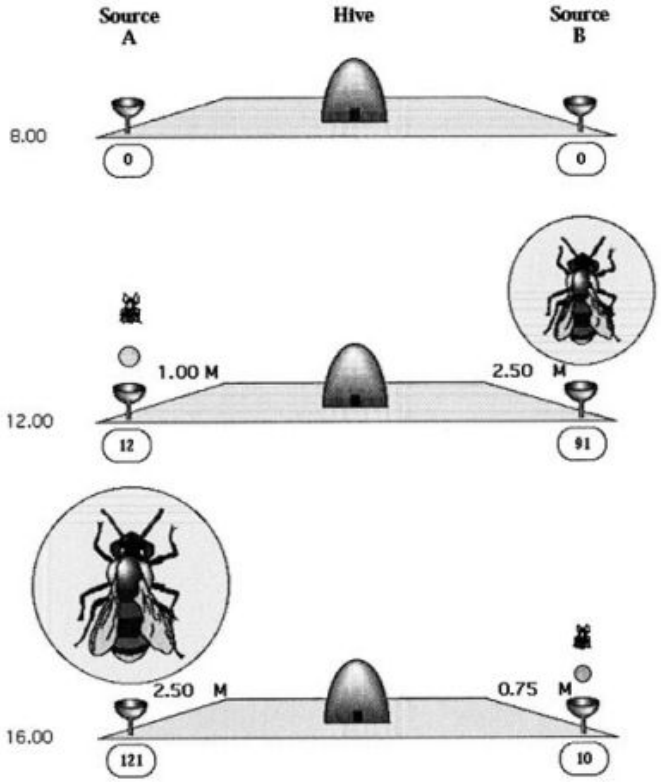
- Set of dynamic mechanisms come together whereby structures (or collective activities) **emerge** at the global level
  - Individual rules based on local info
  - Global pattern emerges and is not imposed
- Flexibility - adaptable to changing environments
- Robustness - functionality despite individual failures

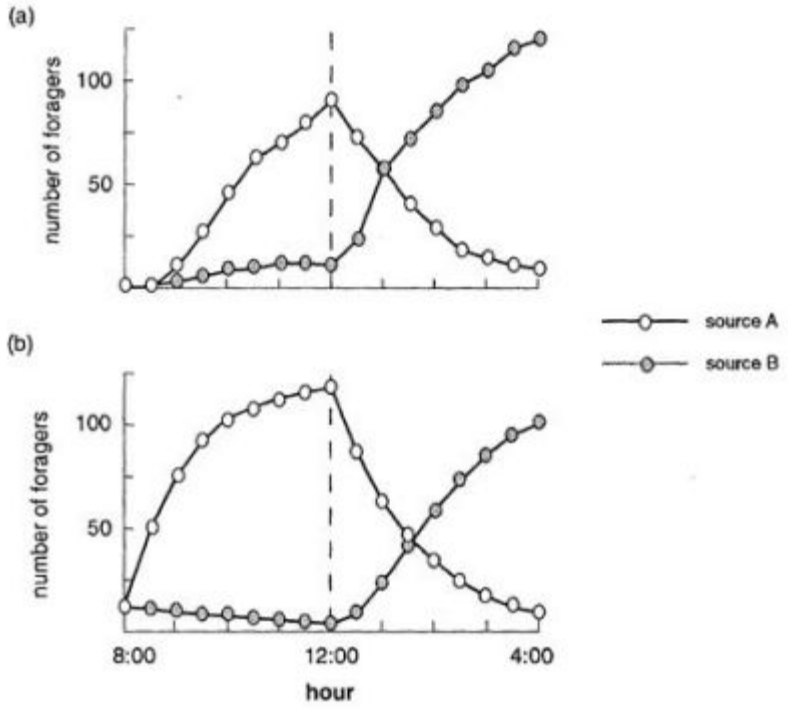
Self-organization can occur via direct or indirect interactions

# Self Organization

- Positive feedback
  - Recruitment and reinforcement
- Negative feedback
  - Exhaustion, saturation or competition
- Amplification of fluctuation
  - Random errors
- Multiple interactions
  - Collaboration of work
  - Make use of result of others activity




Source A
Hive
Source B
8.00
0
0
1.00 M
2.50 M
12.00
12
91
2.50 M
0.75 M
16.00
121
10

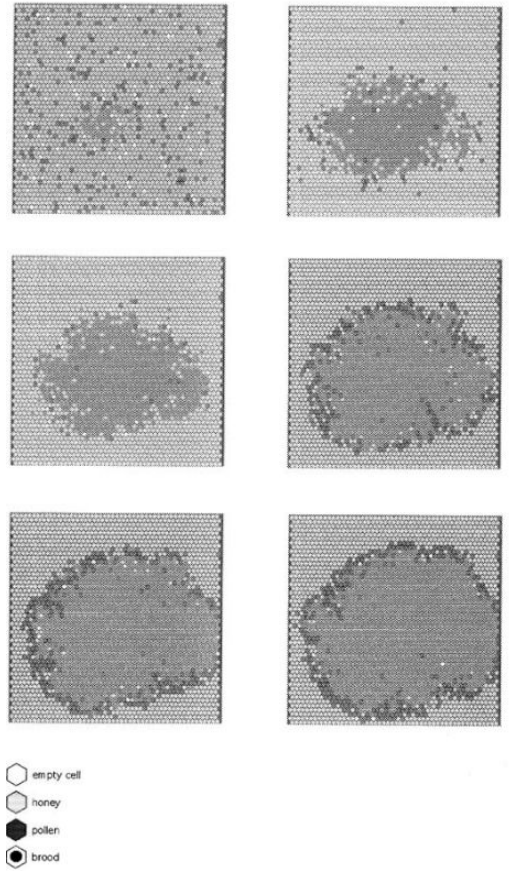

(a)
number of foragers
100
50
(b)
number of foragers
100
50
8:00
12:00
4:00
hour
source A
source B

# 3 key properties of self organization

- The creation of spatiotemporal structures in an initially homogeneious medium
  - Ex. Pattern developed on combs of honeybee colonies
- The possible coexistence of several stable stages
  - Ex. Food source of bees example
- The existence of bifurcation when some parameters are varied
  - Non-coordinate stage: radom moves of individual
  - Coordinate stage: start if the group grows big
  - Ex. building pillars from soil pellets in termite

# Pattern developed on combs of honeybee colonies

A. The queen moves more or less randomly over the combs and lays most eggs in the neighborhood of cells already occupied by brood. Eggs remain in place for 21 days.
B. Honey and pollen are deposited in randomly selected available cells.
C. Four times more honey is brought back to the hive than pollen
D. Typical removal input ratios for honey and pollen are 0.6 and 0.95, respectively.
E. Removal of honey and pollen is proportional to the number of surrounding cells containing brood.



# Self-Organized Secret Weapon: Stigmergy

Stigmergy - **Indirect interaction** between individuals where **one modifies the environment**, and the **other responds to the environment** at a later time

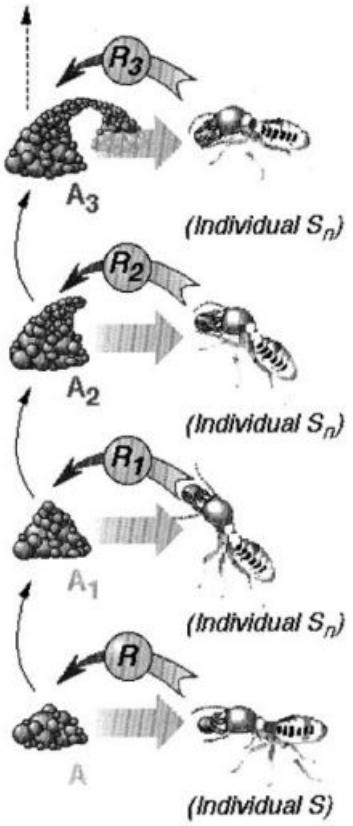
- Mechanism relating individual and colony-level behavior
- Simplifies agents → they don’t need to communicate directly
- Incremental construction toward ‘solution’
- Responsive to environmental change

# Stigmergy Example: Termite Mound Construction

Stimulating configuration of nest structure triggers specific actions in termite workers

- Strips/pillars→arches→walls

Diagram: state of architecture A triggers response A



# Swarm Intelligence and Robotics

Instead of building one complex robot, build several simple ones

- More false tolerant, flexible, self organized

Problem

- Stagnation
- Communications between robots

Thank you! Questions?