
# The Shanghai Lectures 2019

**HeronRobots** ***Pathfinder Lectures***

**Natural and Artificial Intelligence in Embodied Physical Agents**

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# The ShanghAI Lectures

## An experiment in global teaching

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The ShanghAI Lectures and Heron Robots

欢迎您参与
“来自上海的人工智能系列讲座”

# Lecture 3

Emerging Intelligence:

Cognition from Interaction, Development and Evolution

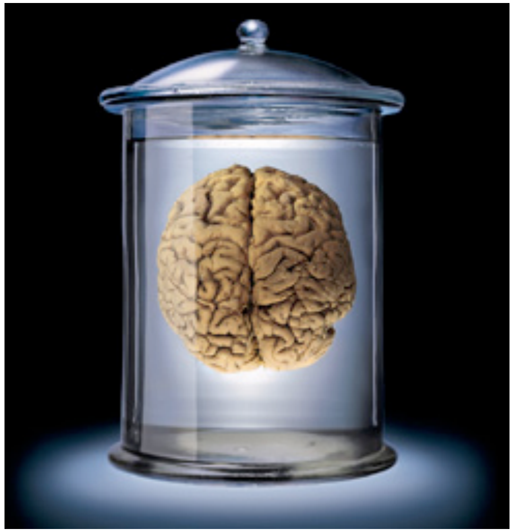
21 November 2019

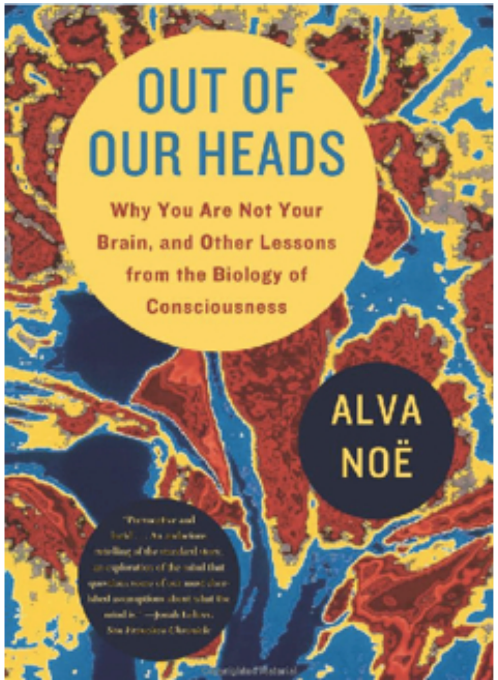
# Today's topics

- brain-in-a-vat
- short recap
- self-organization at many levels
- self-organization and emergence in groups of agents
- modular robotics and self-assembly
- design principles for collective intelligence

# “Brain-in-a-vat”

Alva Noë, “Out of our heads - why you are not your brain”, New York, Hill and Wang, 2009

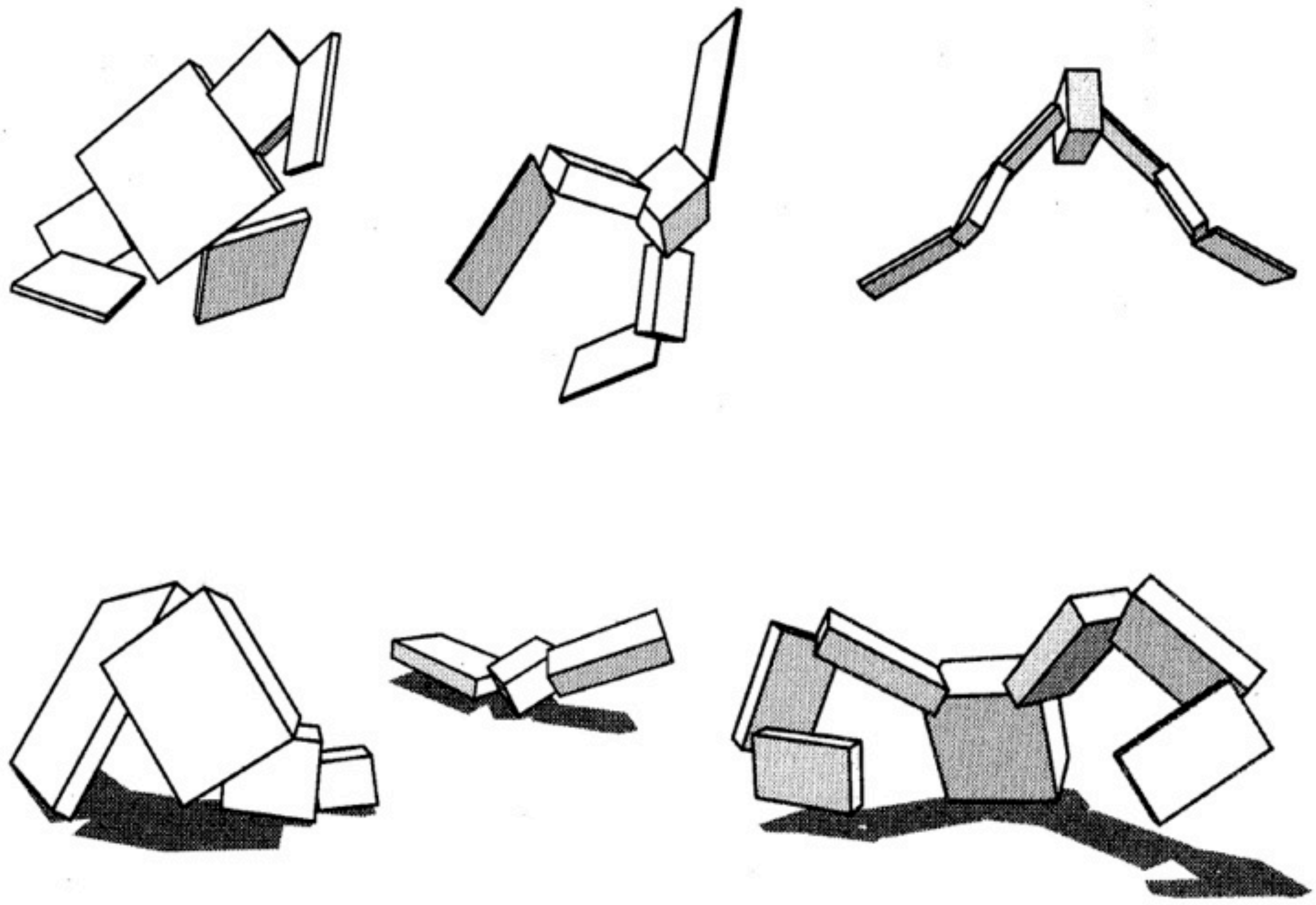





# Short recap

- given robot → evolve control (neural network)
- embodied approach → co-evolution of morphology and control

# Evolving morphology and control: Karl Sims's

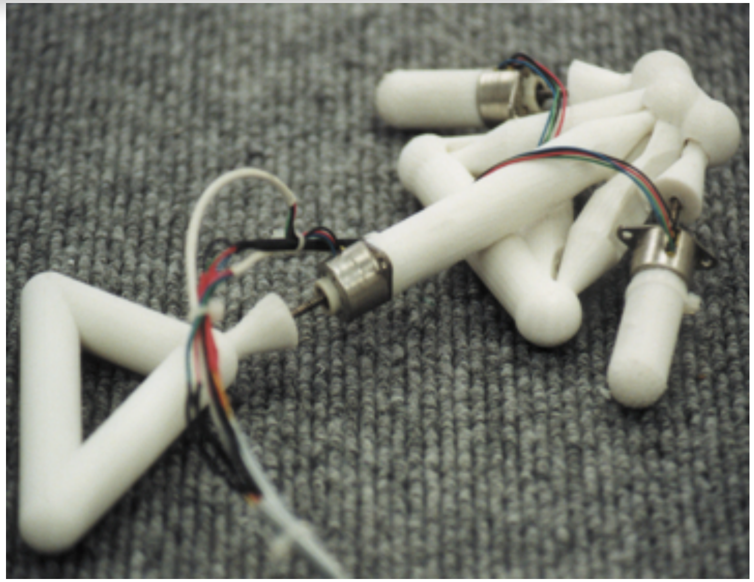


# New version: Golem (Lipson and Pollack)

representation of morphology in genome

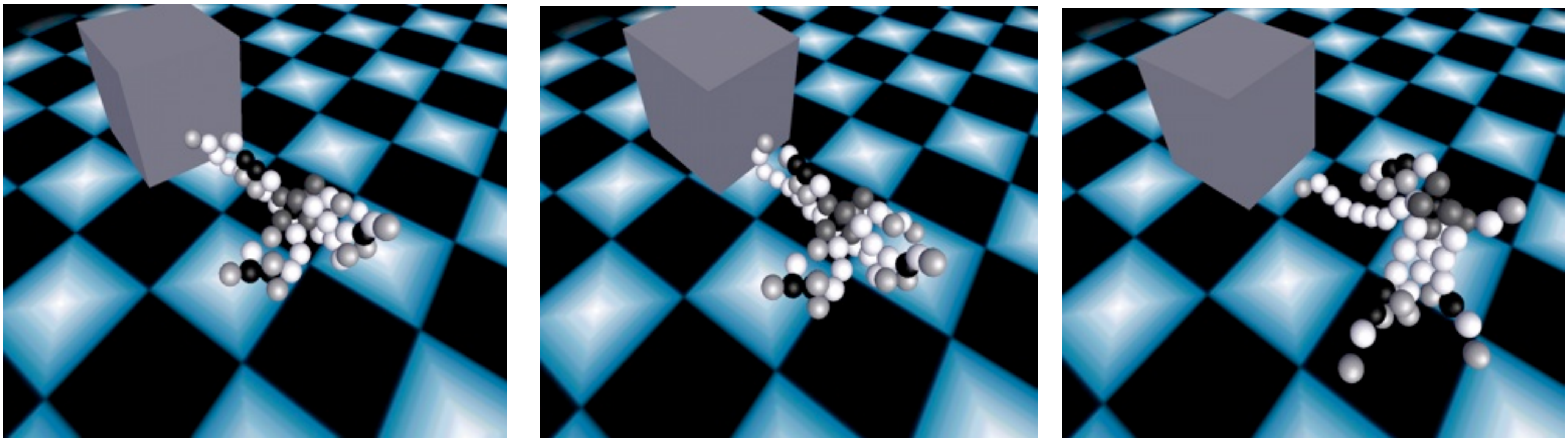
- robot: bars, actuators, neurons
- bars: length, diameter, stiffness, joint type
- actuators: type, range
- neurons: thresholds, synaptic strengths

(recursive encoding)

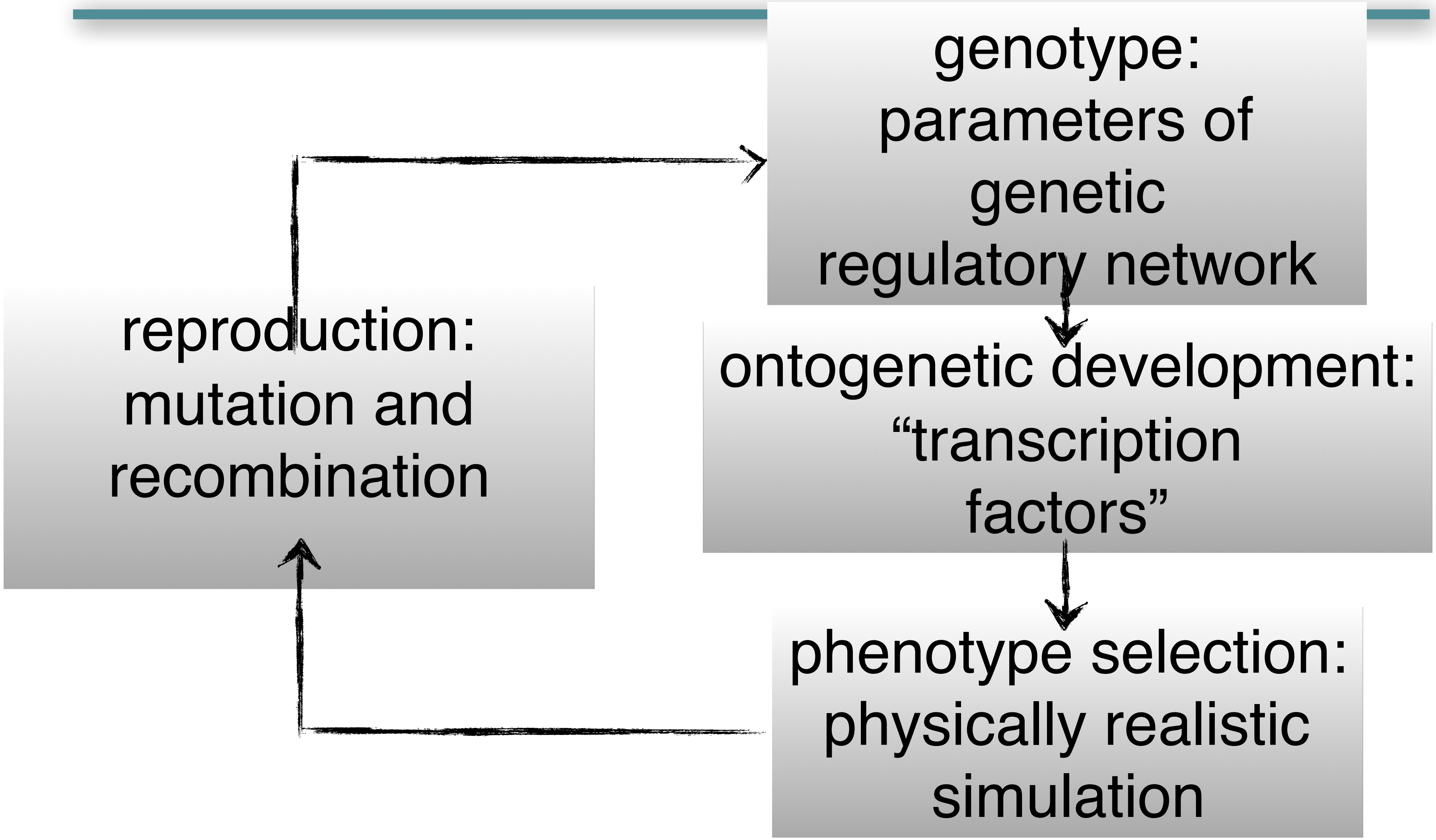


# Genetic Regulatory Networks (GRNs): Bongard's "block

- development (morphogenesis) embedded into evolutionary process, based on GRNs
- testing of phenotypes in physically realistic simulation

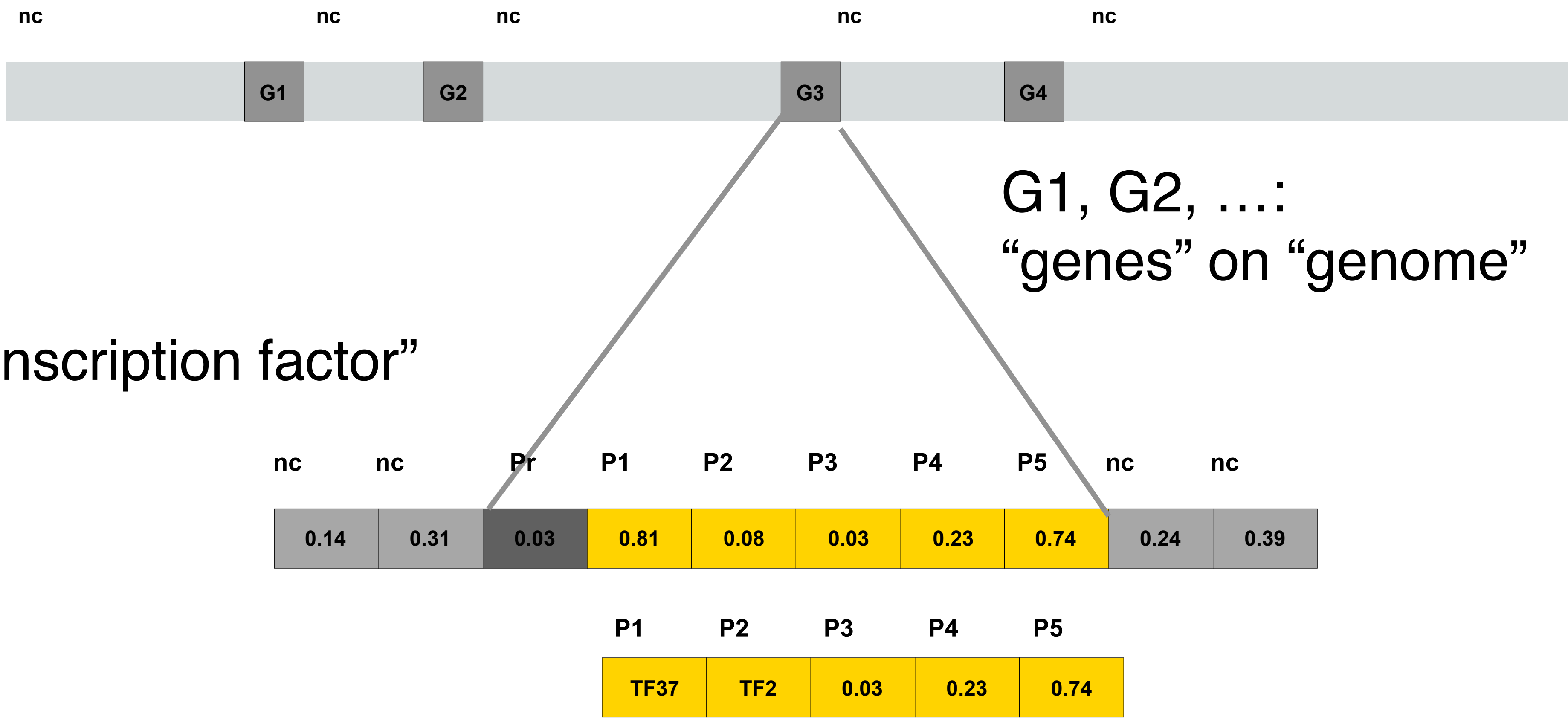


# Bongard's evolutionary scheme



# Representation of “gene”

nc: “non-coding region”




G1, G2, …:
“genes” on “genome”

TF: “transcription factor”

# Limitations of artificial evolution?

think about:

Where are the limits of artificial evolution?

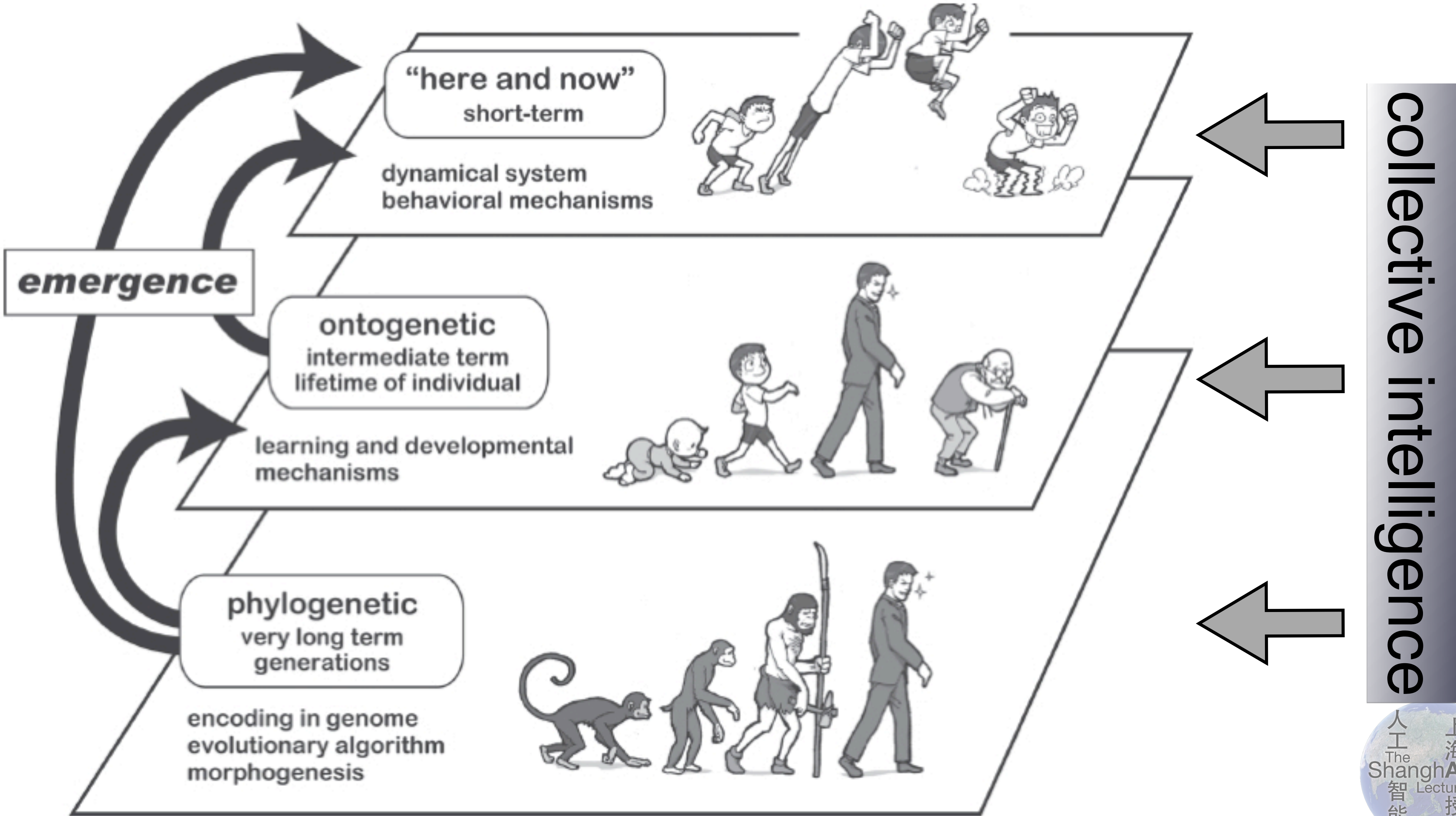
Or is the potential unlimited?

# Collective intelligence

# Self-organization and emergence at many levels

- molecules
- cells
- organs
- individuals
- groups of individuals

# Time perspectives



# Time perspectives in understanding and design

state-oriented
"hand design"

"here and now" perspective

learning and development
initial conditions, learning and developmental processes

"ontogenetic" perspective

evolutionary
evolutionary algorithms,

"phylogenetic" perspective

collective intelligence

Understanding: all three perspectives requires
Design: level of designer commitments, relation to autonomy
Collective intelligence: emergence from interaction

# Examples of collective behavior — self-organization

bee hive

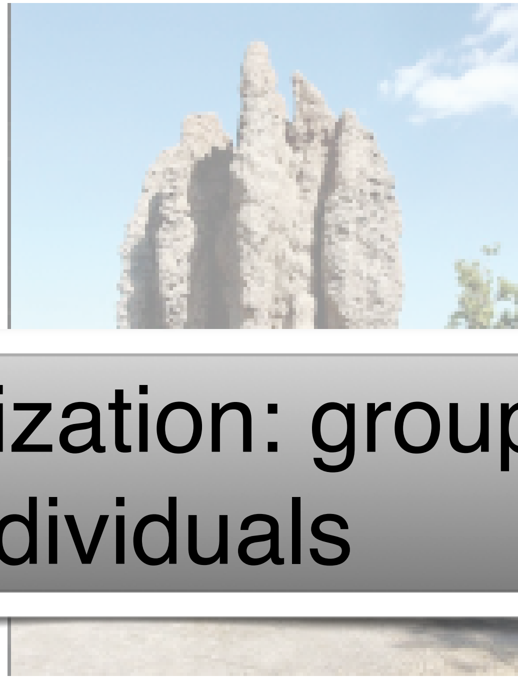
termite mound

“wave”in stadium

open source development community

# Examples of collective behavior — self-organization

bee



self-organization: groups of individuals

e”in stadium

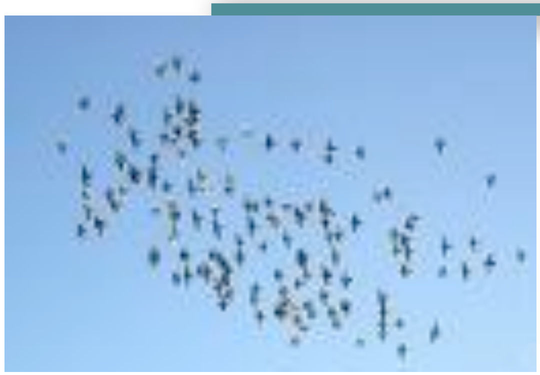
termite mound

open source development community

# Recall: Emergence

- collective behavior: global patterns from local interactions (e.g. “Swiss Robots”, bird flocks, clapping)
- behavior of individual: emergent from interaction with environment
- from time scales

# Swarm behavior



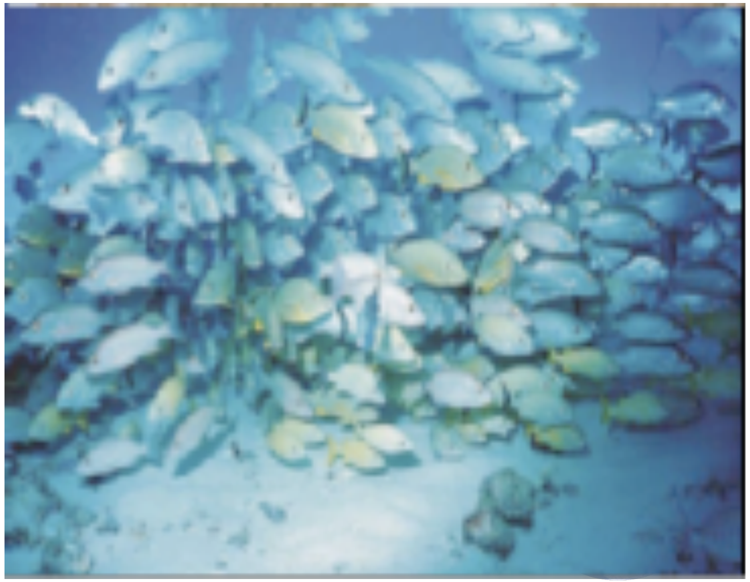
birds

humans

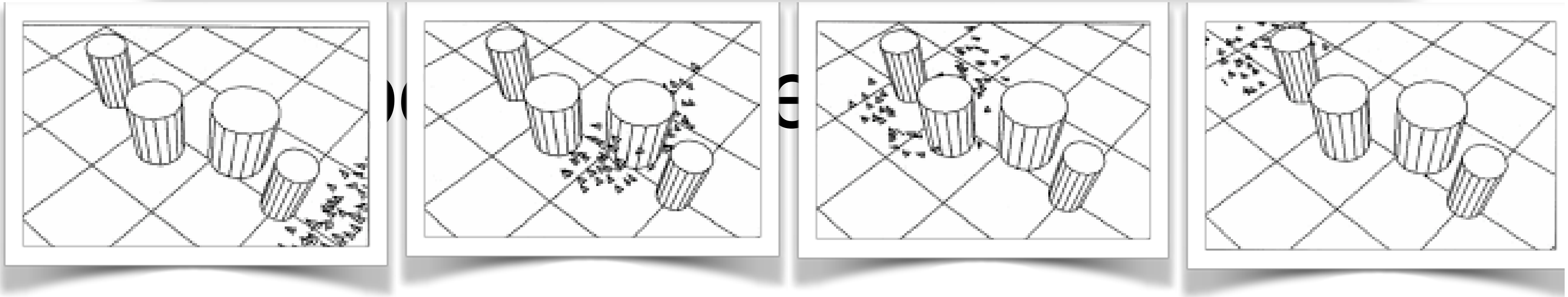
sheep

insects

fish



# Craig Reynolds's flocking rules

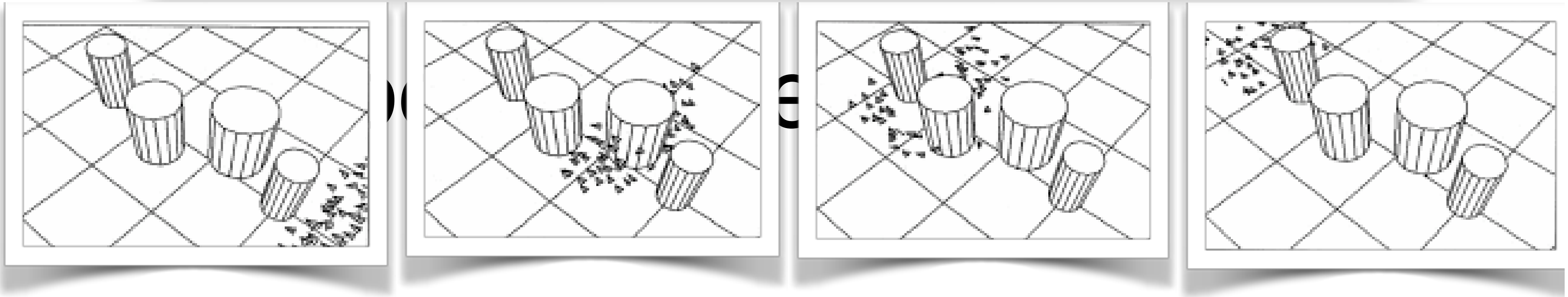


1.

2.

3.

# Craig Reynolds’s flocking rules



1. Collision avoidance: Avoid collisions with nearby flockmates (and other objects)
2. Velocity matching: attempt to match velocity of nearby flockmates
3. Flock centering: attempt to stay nearby flockmates

# Problem to think about: Modeling swarm behavior

frame-of-reference?

situated vs. “god’s eye view”

“god’s eye view”: straightforward

situated view: biologically more plausible but more difficult to implement

# Design principles for collective systems

Principle 1: Level of abstraction

Principle 2: Design for emergence

Principle 3: From agent to group

Principle 4: Homogeneity/heterogeneity

# Assignments for next week

- Check "How the body…" for self-study
- Think about how to design a simulation model for flocking from a situated perspective

# End of lecture 3

Thank you for your attention!

stay tuned for lecture 4