人工智能 The ShanghAI Lectures 上海授课

Calling on

- Lodz —> short presentation on “brain in a vat”
- Chiba —> short comment on the limitations/potential of simulated evolution
- Osaka —> short comment on cooperation
- Shanghai —> implementation of the “situated” perspective of flocking (rather than the “god’s eye” perspective)
- Salford, UK —> additional example of emergence in group behavior
- HITLab, UTAS —> explanation of how ants can find the shortest way to a food source, and perhaps simulation
- SKKU - Seoul —> comment on crowdsourcing as swarm behavior
- Karlsruhe —> how does the self-assembly of the “bicycle” work? (speculation)

Videos

- Simulation of ant behavior
- MTRAN
- Pizza self-assembly
- Pizza emergent-functionality (where the pizzas are turning)
- The emergent self-assemble bicyle - bike4 (where the two disks and the triangle self-assemble)

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Today's schedule

09.00 - 09.05 Introductory comments, announcing the winners of the F-O-R competition (last week)

09.05 - 09.15 Chris's presentation on the "brain in a vat" from Lodz, Poland

09.15 - 09.55 Collective intelligence: cognition from interaction

09.55 Break

10.00 - 10.30 Istvan Harmati, Budapest

10.30 - 11.00 Nikoalos Mavridis, NYU Abu Dhabi Campus "The human-robot cloud: Towards situated, collective large-scale human-robot intelligence"

Exercises: problems, please do send e-mail; ideas you like to share --> use forum on website.
worldmaster@shanghailectures.org

The ShanghAI Lectures by the University of Zurich An experiment in global teaching

Today from the University of Zurich, Switzerland

22 November 2012

欢迎您参与

“来自上海的人工智能系列讲座”

Lecture 7

Collective intelligence:
Cognition from interaction

22 November 2012

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F-O-R competition: the lucky winner

presented by Prof. Verena Hafner

Jan Gosmann

Congratulations!

Swiss Chocolate

Should I forget to mention the FOR problem in any of the lectures, the first to discover will get either a box of Swiss chocolate or a bottle of champagne. If there is one idea from the class that everyone should remember, it’s the FOR problem.

Today's topics

- presentation from Yana on "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

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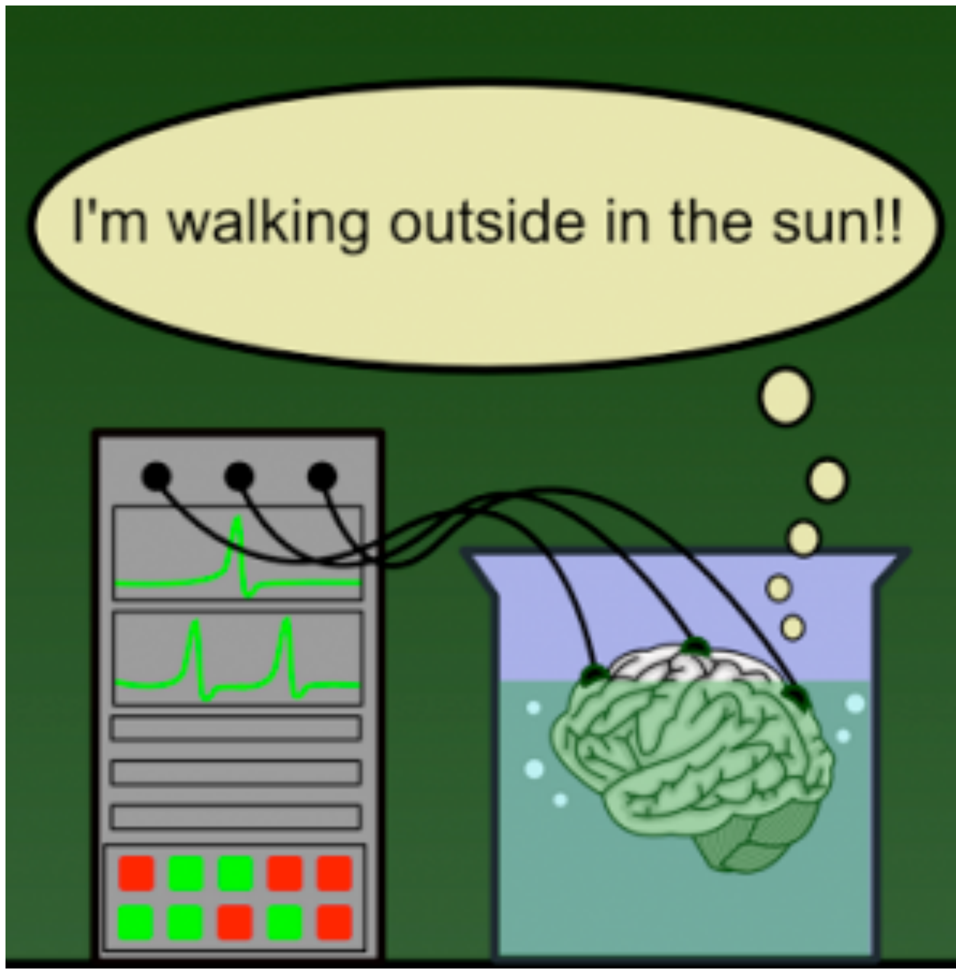
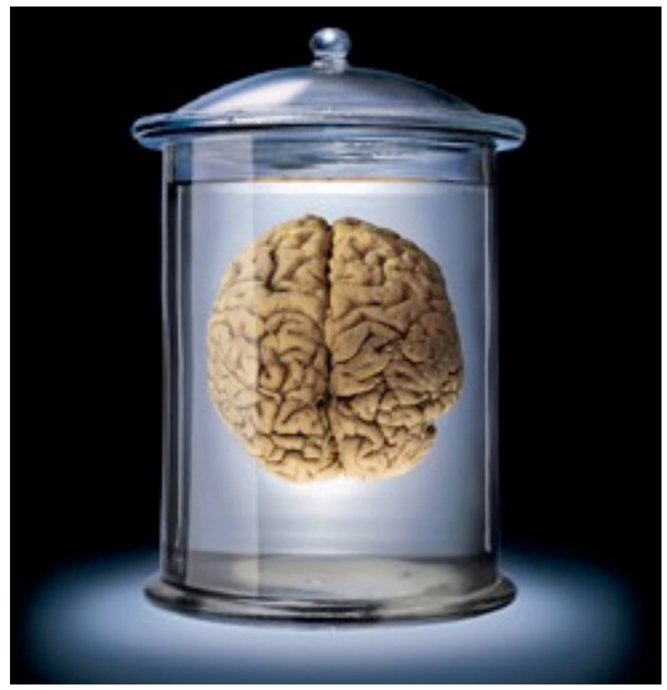
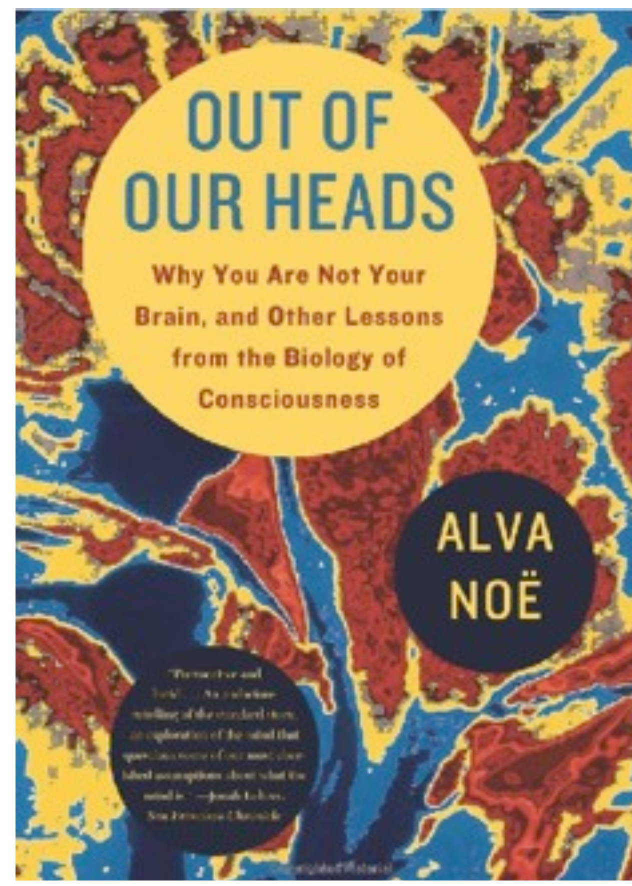


"Brain-in-a-vat"

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



Short presentation by Yana from RGGU, Moscow



—> Switch to Lodz, Poland

"Consider, first of all, that the vat or petri dish, couldn't be a mere dish or bucket as Evan Thompson and Diego Cosmelli have discussed in an essay. It would have to supply energy to nourish the cells' metabolic activity and it would have to be capable of flushing away waste products. The vat would have to be very complicated and specialized in order to control the administration of stimulation to the brain comparable to that normally provided to the brain by its environmentally situated body. If you actually try to think through the details of this thought experiment – this is something scientists and philosophers struck by the brain-in-a-vat idea almost never do – it's clear that the vat would have to be, in effect, something like a living body." (Alva Noe, Out of our heads, p. 12/13).

Short presentation on “brain in a vat”

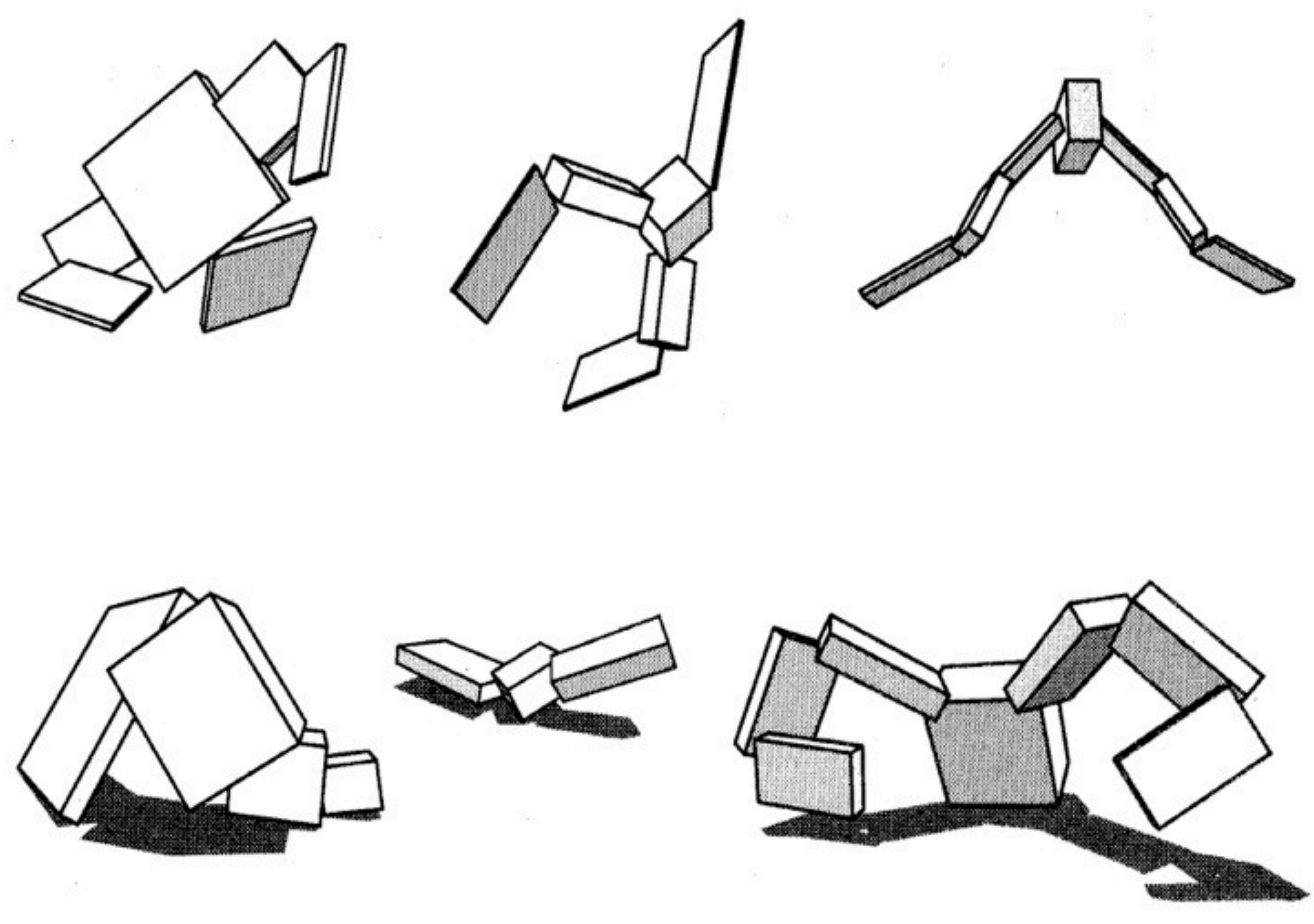
Lodz
Poland

Short recap

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

embodied approach:
1. parameterization —> Sims, Lipson and Pollack, Komosinski and Ulatowski
2. GRNs —> Eggenberger, Bongard

Evolving morphology and control: Karl Sims's creatures

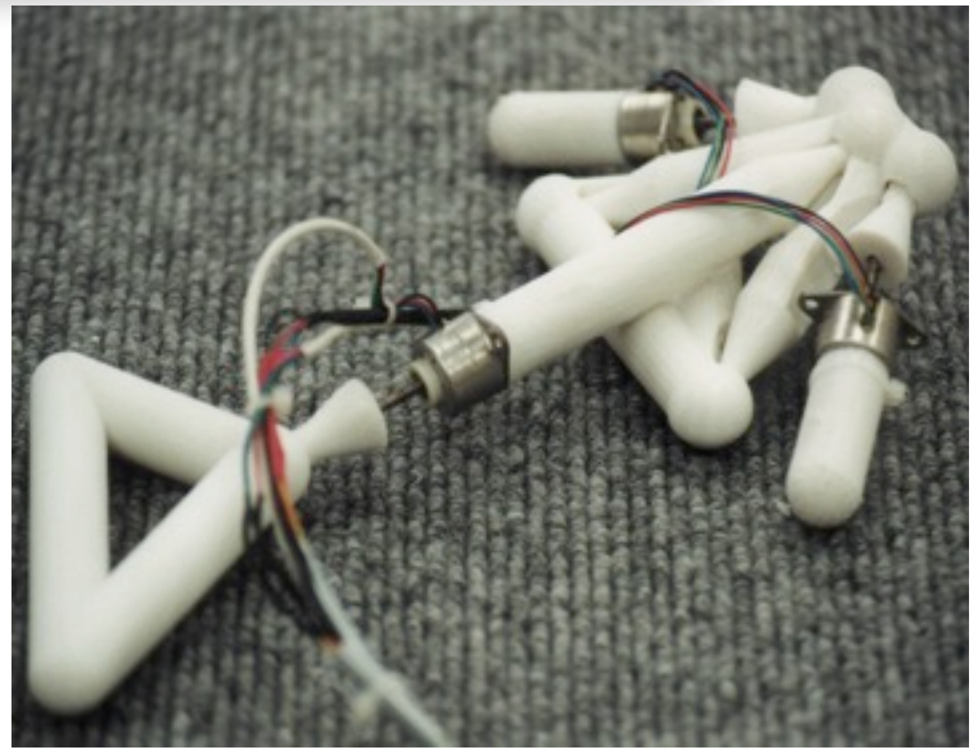


New version: Golem (Lipson and Pollack)

representation of morphology in genome

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

(recursive encoding)



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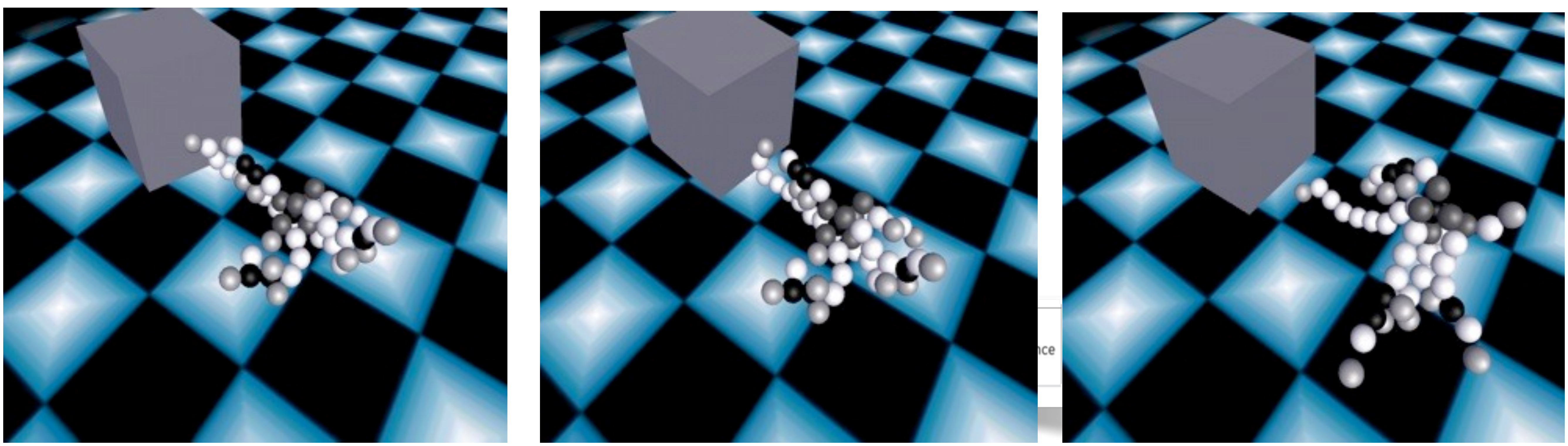
Genetic Regulatory Networks (GRNs): Bongard's "block pushers"

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



Bongard's evolutionary scheme

genotype:
parameters of genetic regulatory network

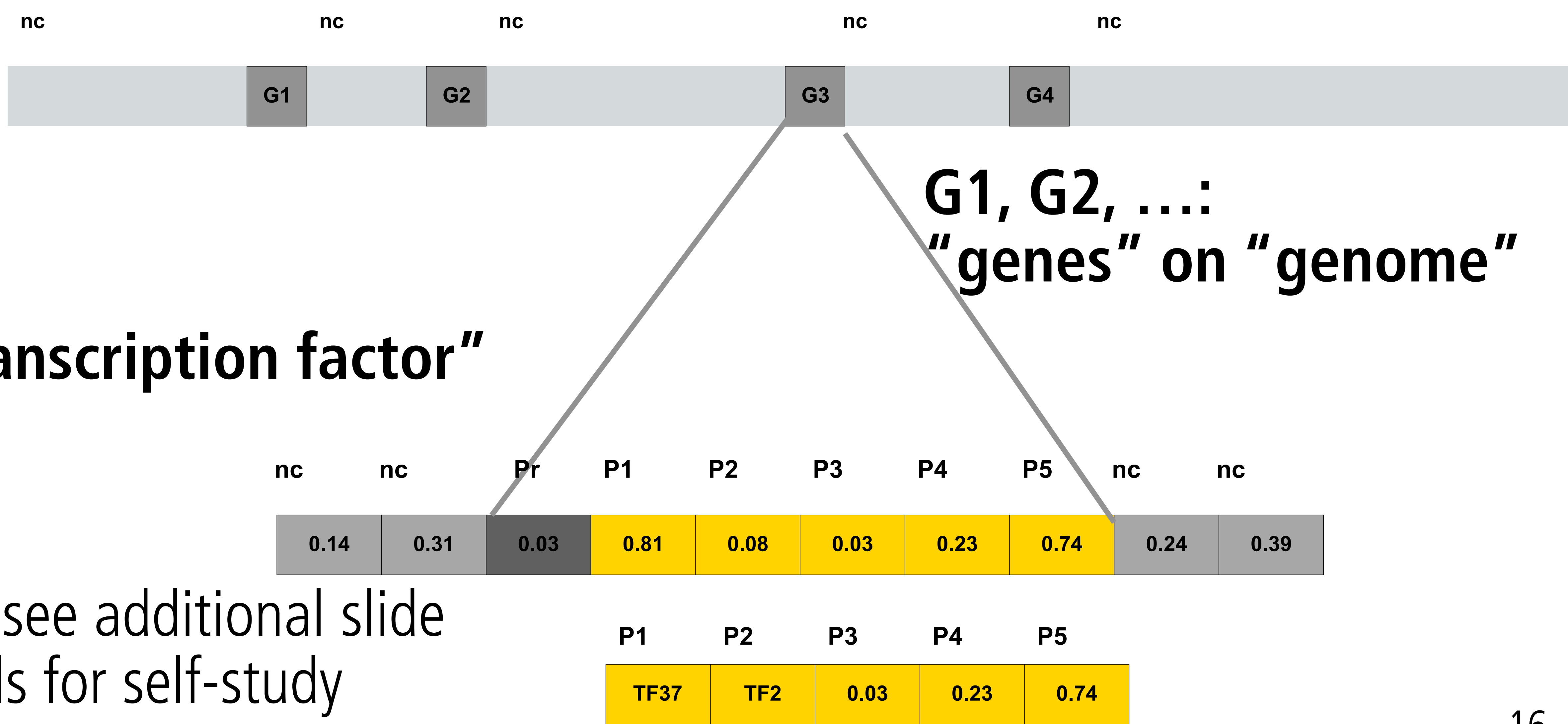
ontogenetic development:
"transcription factors"

phenotype selection:
physically realistic simulation

reproduction:
mutation and recombination

Representation of “gene”

nc: “non-coding region”



G1, G2, …: “genes” on “genome”

TF: “transcription factor”

Details: see additional slide materials for self-study

Simplified model of GRN (Genetic Regulatory Network). The transcription factors are pre-defined and the parameters of the genes are under evolutionary control.

Limitations of artificial evolution?

think about:

—> Where are the limits of artificial evolution?

Or is the potential unlimited?

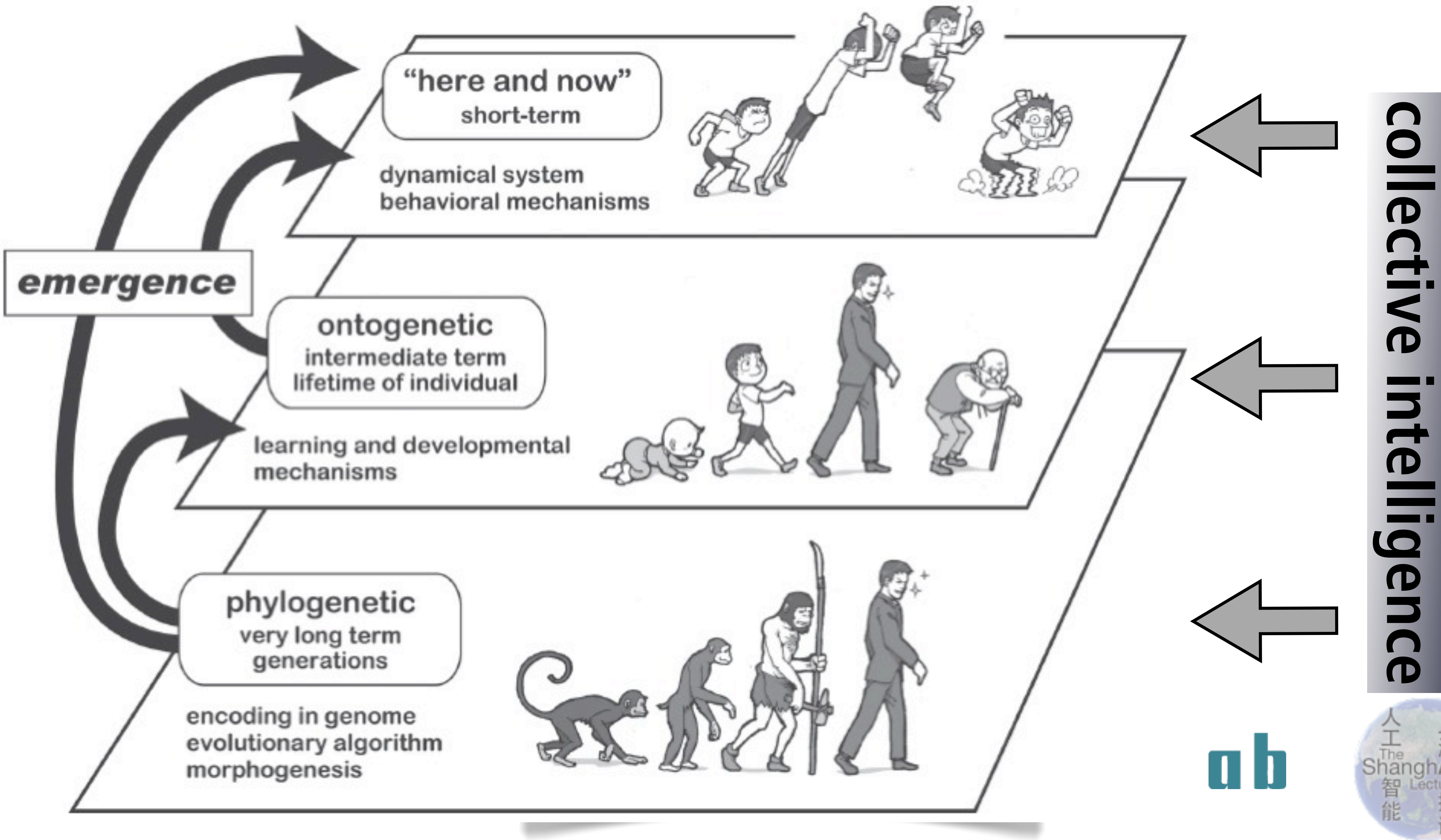
—> Chiba

Collective intelligence

Self-organization and emergence at many levels

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

Time perspectives



Time perspectives in understanding and design

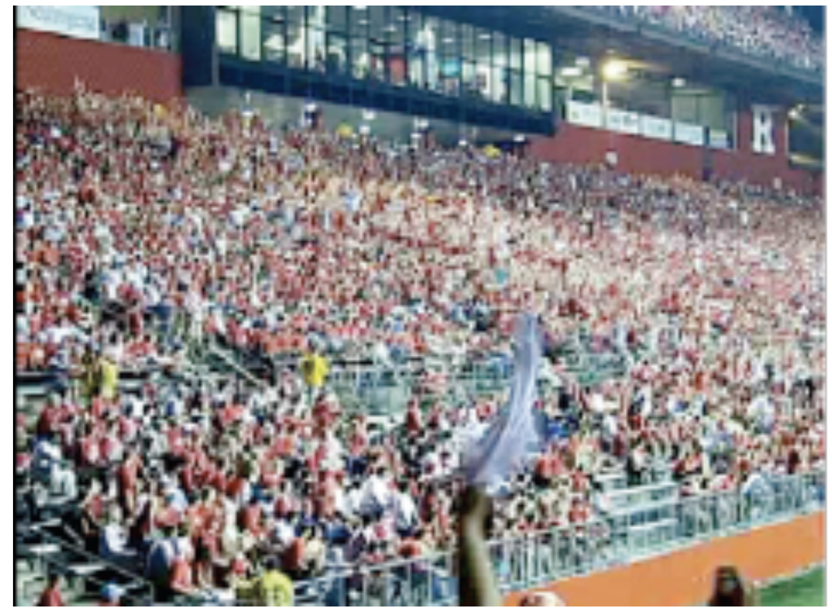
state-oriented **"hand design"**	"here and now" perspective	collective intelligence
learning and development **initial conditions, learning and developmental processes**	"ontogenetic" perspective	
evolutionary **evolutionary algorithms, morphogenesis**	"phylogenetic" perspective	

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

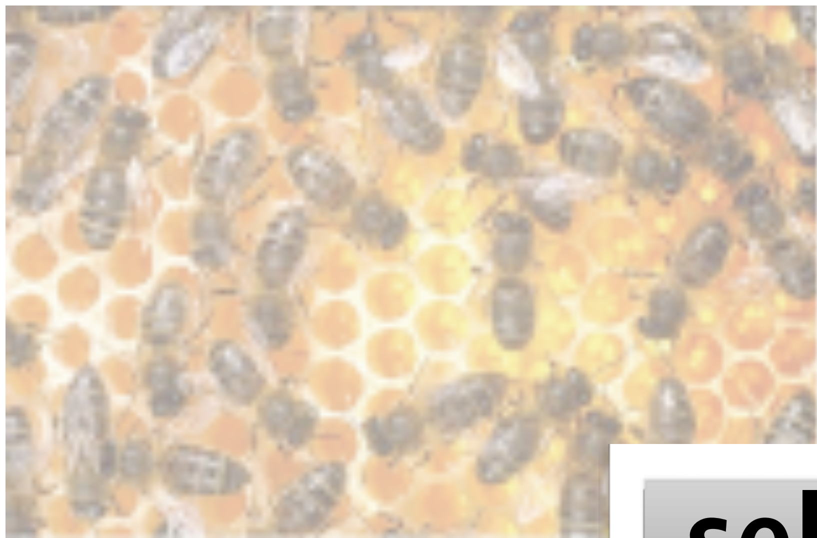
termite mound



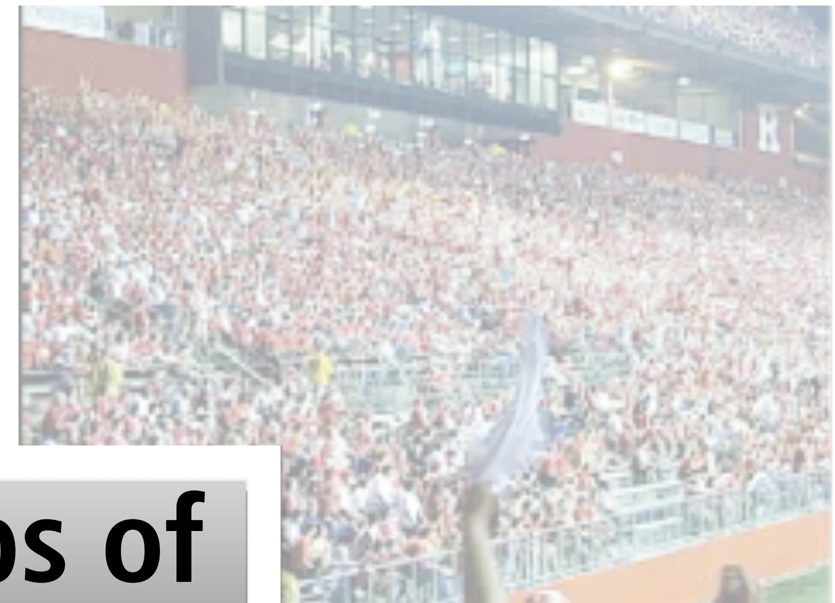
"wave" in stadium

open source development community

Examples of collective behavior — self-organization



bee



self-organization: groups of individuals

”in stadium

termite mound

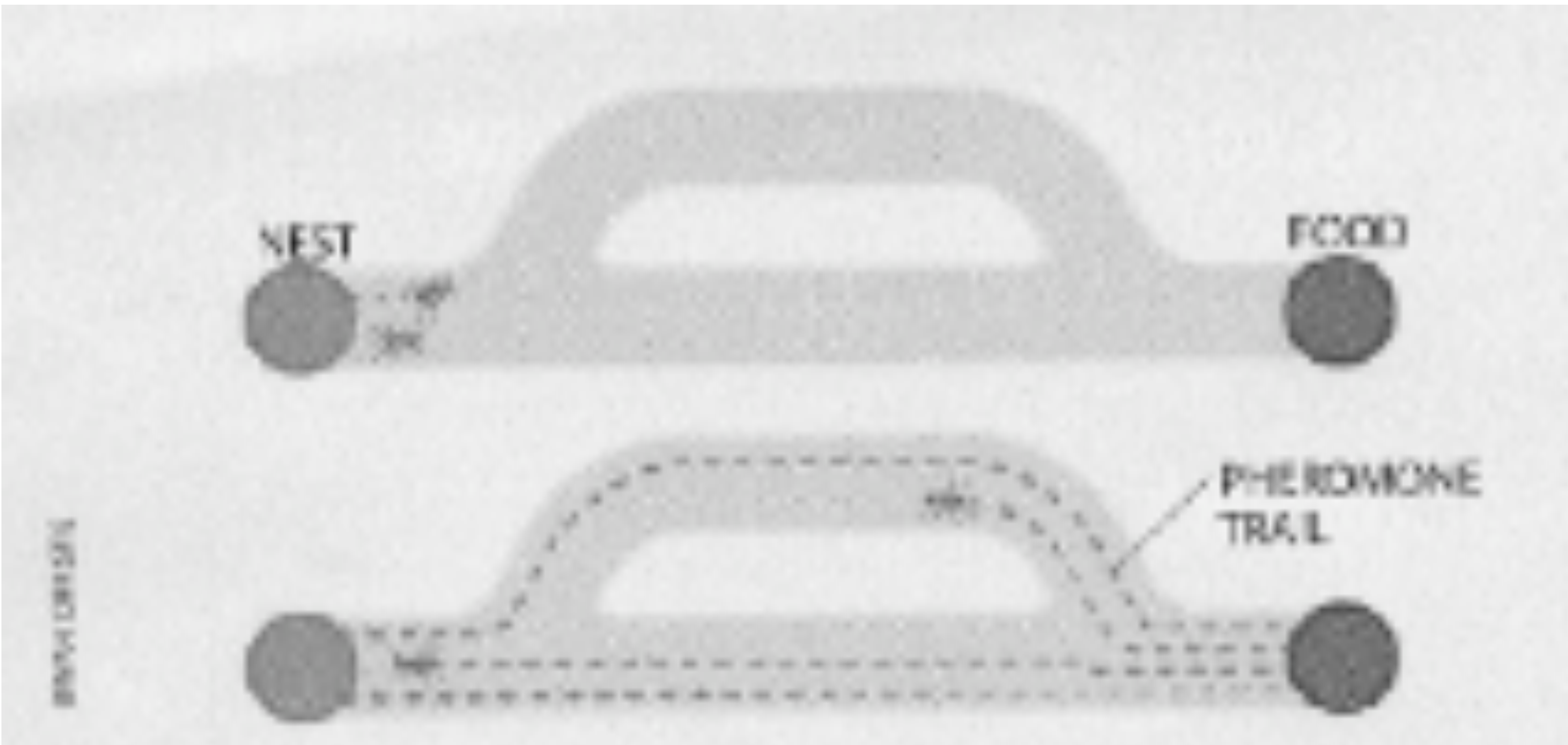
open source development community

Ants finding the shortest path to a food source

Explanation and demonstration —> HITLab, Tasmania

explanation from HIT Lab
for a “cognitivistic explanations”considerable cognitive capacities are required, e.g. memory, comparison mechanism
Mention: Stygmergic interactions (through the interaction with the environment)

Finding the shortest path to a food source



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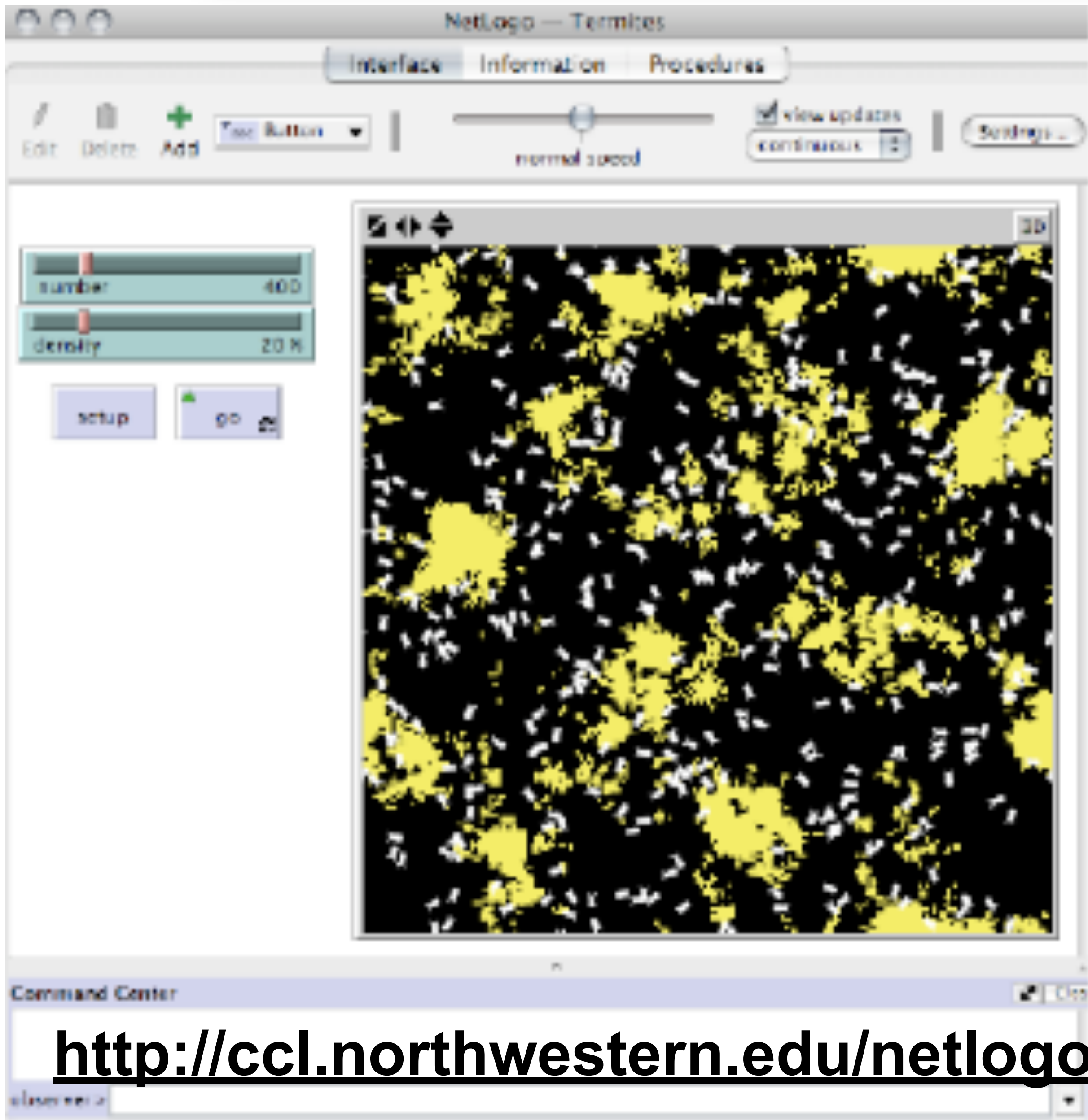
Pheromone trails enable ants to search for food efficiently: Two ants leave the nest at the same time (top), each taking a different path and marking it with pheromone. The ant that took the shorter path returns first (bottom). Because this trail is now marked with twice as much pheromone, it will attract other ants more than the longer route will.

WARNING: holds not only for ants, but also for humans!!!

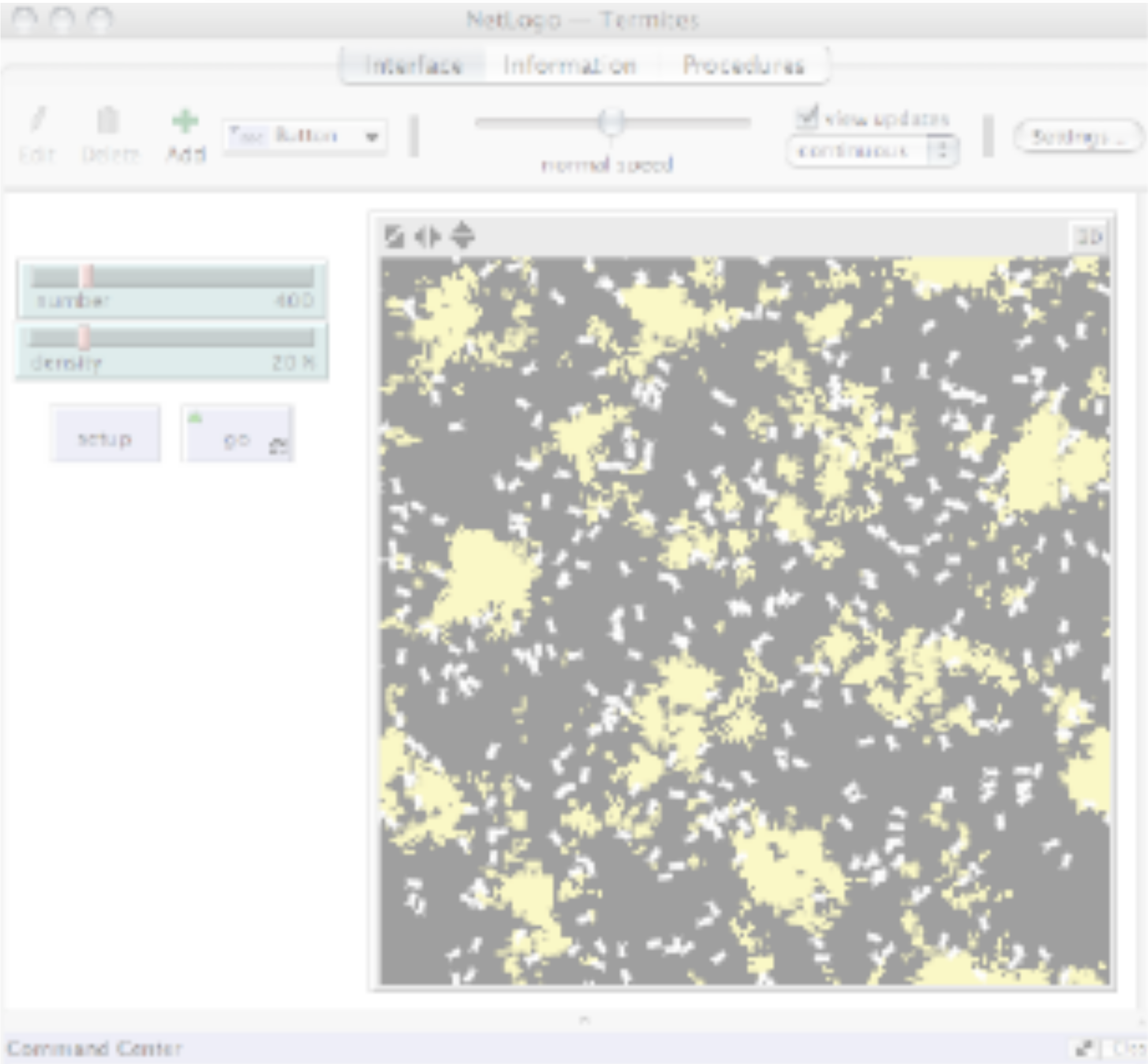
Simulation



Mitchell Resnick, MIT: "Turtles, Termites and Traffic Jams"
MIT Press, 1997.

http://ccl.northwestern.edu/netlogo/models/run.cgi?Ants.790.569

Simulation



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

Original development:
Starlogo
Mitchell Resnick, MIT: “Turtles, Termites and Traffic Jams”
MIT Press, 1997.

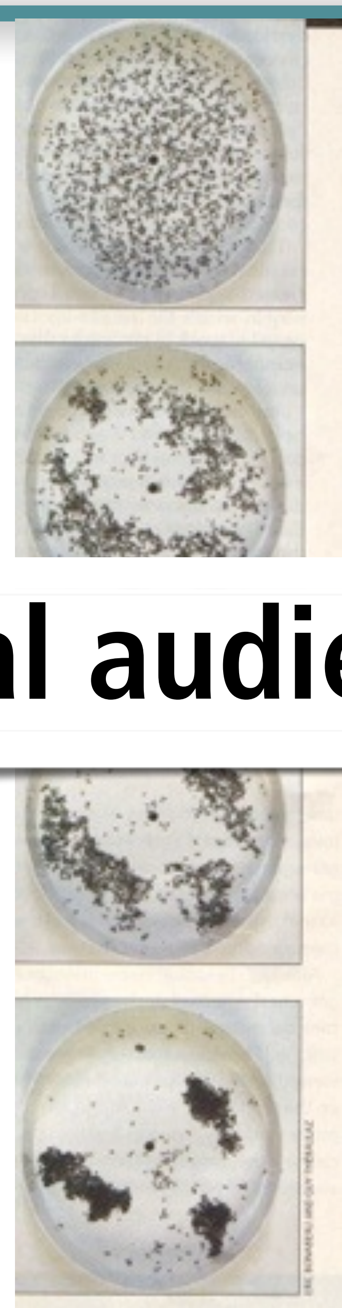
Recall: Emergence

- 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

Emergence is gradual, not all or none: the more I my designer commitments back, the more the behavior of the resulting agent(s)/system will be emergent.

Recall:
"Swiss Robots" — real ants

"Swiss Robots": mechanism?



Real ants: mechanism?

—> local audience in Zurich

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Swiss Robots: "obstacle avoidance"
Real ants: mechanisms unknown, several models have been proposed
from the fact that the result of the interaction with the environment is the same, we cannot conclude that the ants are doing the same thing as the robots, however, it demonstrates that it is a possible solution.

A note on cooperation

what do we really mean by cooperation? (F-O-R!)

- “Swiss robots”?
- ants finding shortest path to food source?
- ants carrying large object?
- people jointly carrying large object?
- soccer and Robocup; crowdsourcing?
- organizing the ShanghAI Lectures project?

A note on cooperation

what do we really mean by cooperation? (F-O-R!)

Short comment on cooperation —> Osaka University

- ants carrying large object?
- people jointly carrying large object?
- soccer and Robocup?
- organizing the ShanghAI Lectures project?

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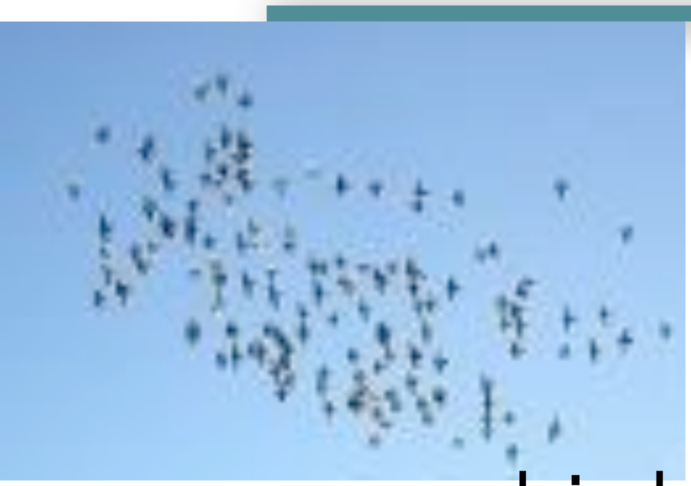
Swarm behavior



birds

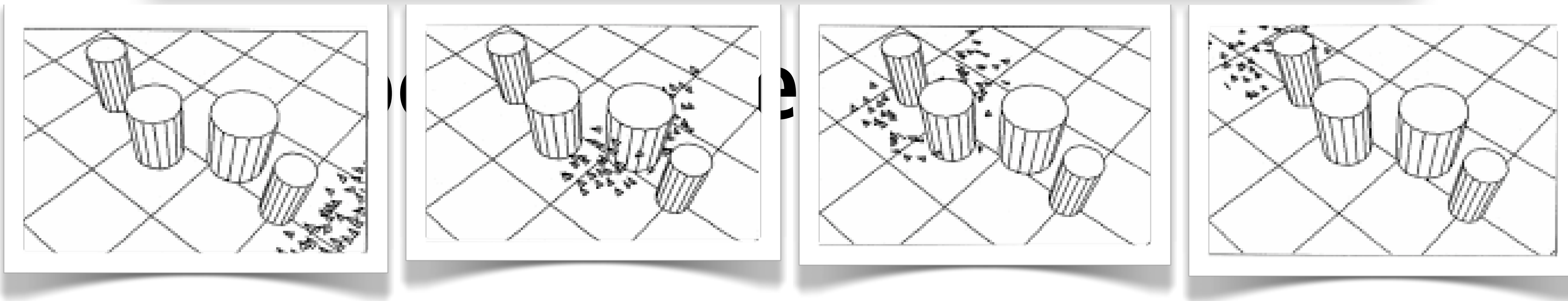
humans

sheep

insects

fish

Craig Reynolds's flocking rules



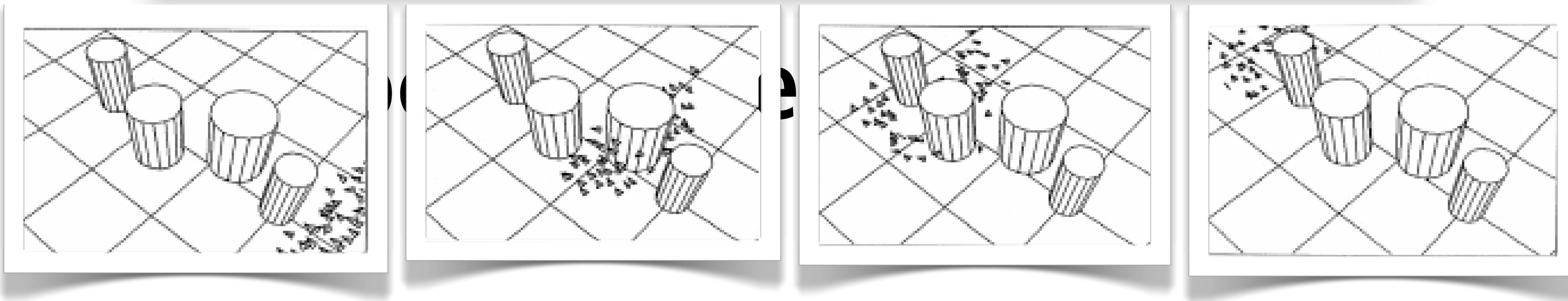
1.

2.

3.

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

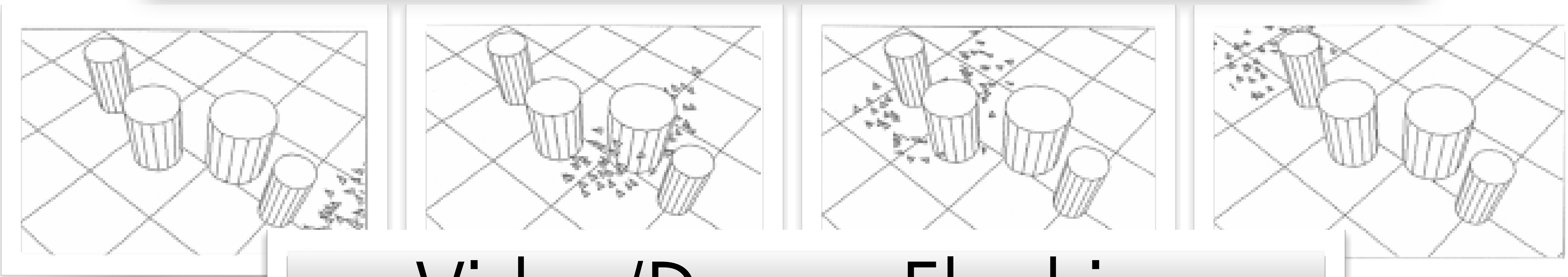
Craig Reynolds's flocking rules



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**

Boids encounter a cluster of pillars. Amazingly, the flock simply splits and rejoins after it has passed the pillars. Note that "splitting" is not contained in the set of rules, but is emergent: the result of several parallel processes while the boids are interacting with their environment (comment: the situation is actually more complicated that described here – for realistic situations, additional rules must be included) (Reynolds, 1987).

Craig Reynolds's flocking rules



Video/Demo: Flocking

1. Collision avoidance: **Avoid collisions with nearby flockmates (and other objects)**

2. Velocity matching: **attempt of match velocity of nearby flockmates**

http://www.lalena.com/AI/Flock/Flock.aspx

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

Problem to think about: Modeling swarm behavior

frame-of-reference?

situated vs. "god's eye view"

"god's eye view": straight forward

situated view: biologically more plausible but more difficult to implement

implementation with situated agents: main points —> Shanghai

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Additional examples of self-organization and emergence

additional example: human or animal world; groups of individuals/agents —> Salford

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traffic jams
people gathering during break
Silicon Valley
deterioration of public transportation
population growth
pattern formation of sea shells
synchronization phenomena (clapping, cicadas, etc.)
(try to think of additional examples)

Crowdsourcing: emergence of innovation?

SKKU - Seoul —> short comment on crowdsourcing
(what do we mean by “crowdsourcing”?
is this swarm behavior?)

Social simulations

- Shelling's segregation model
- Epstein and Axtell's "Sugerscape model"

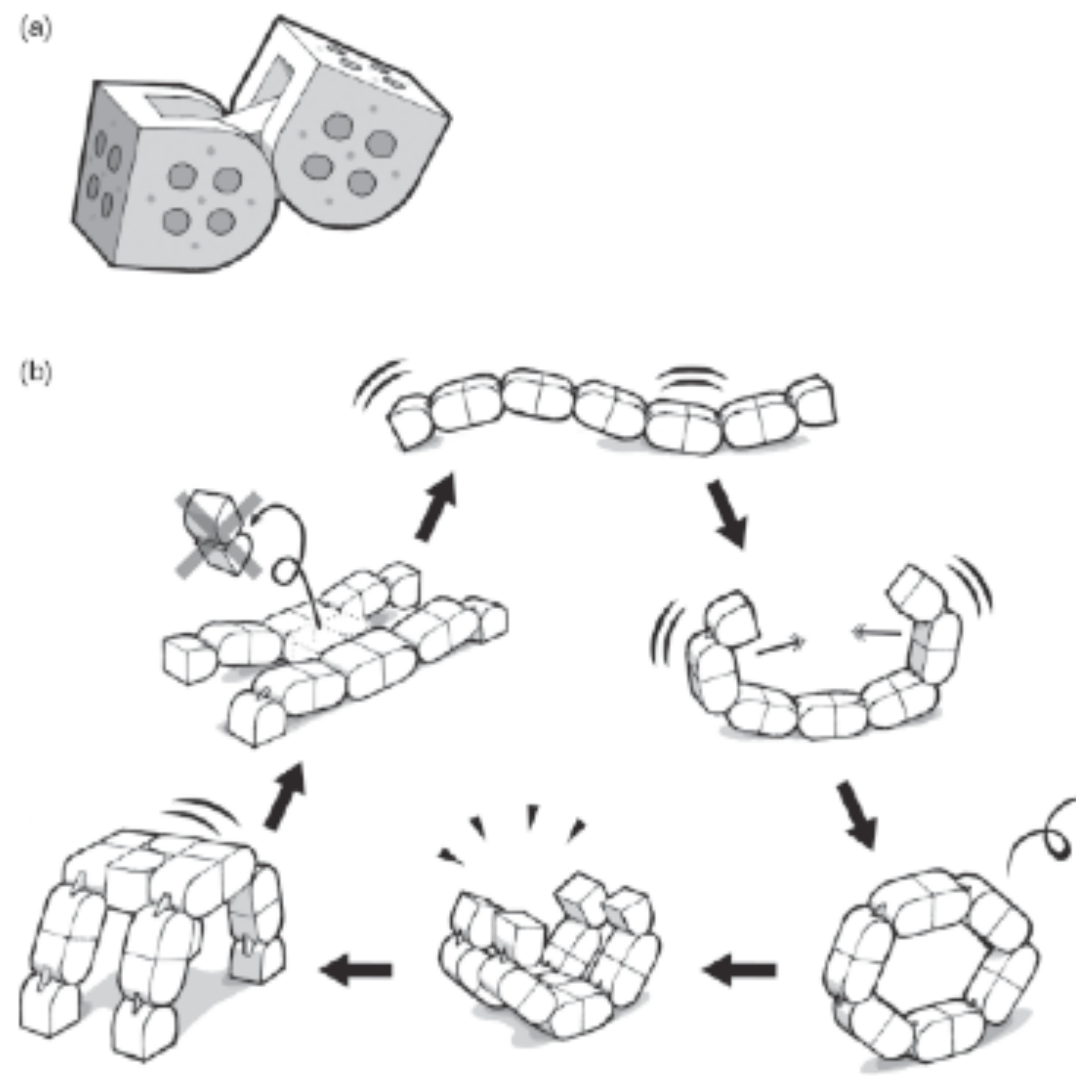
Modular robotics
Motivation

- **change in functionality through change in morphology (puffer fish "Fugu", M-TRAN, Hara's "morpho-functional machines")**
- **adaptivity through morphological change**
- **self-assembly, self-repair, self-reproduction**

"level of abstraction": **modules interacting**

Modular robotics
Satoshi Murata's M-TRAN

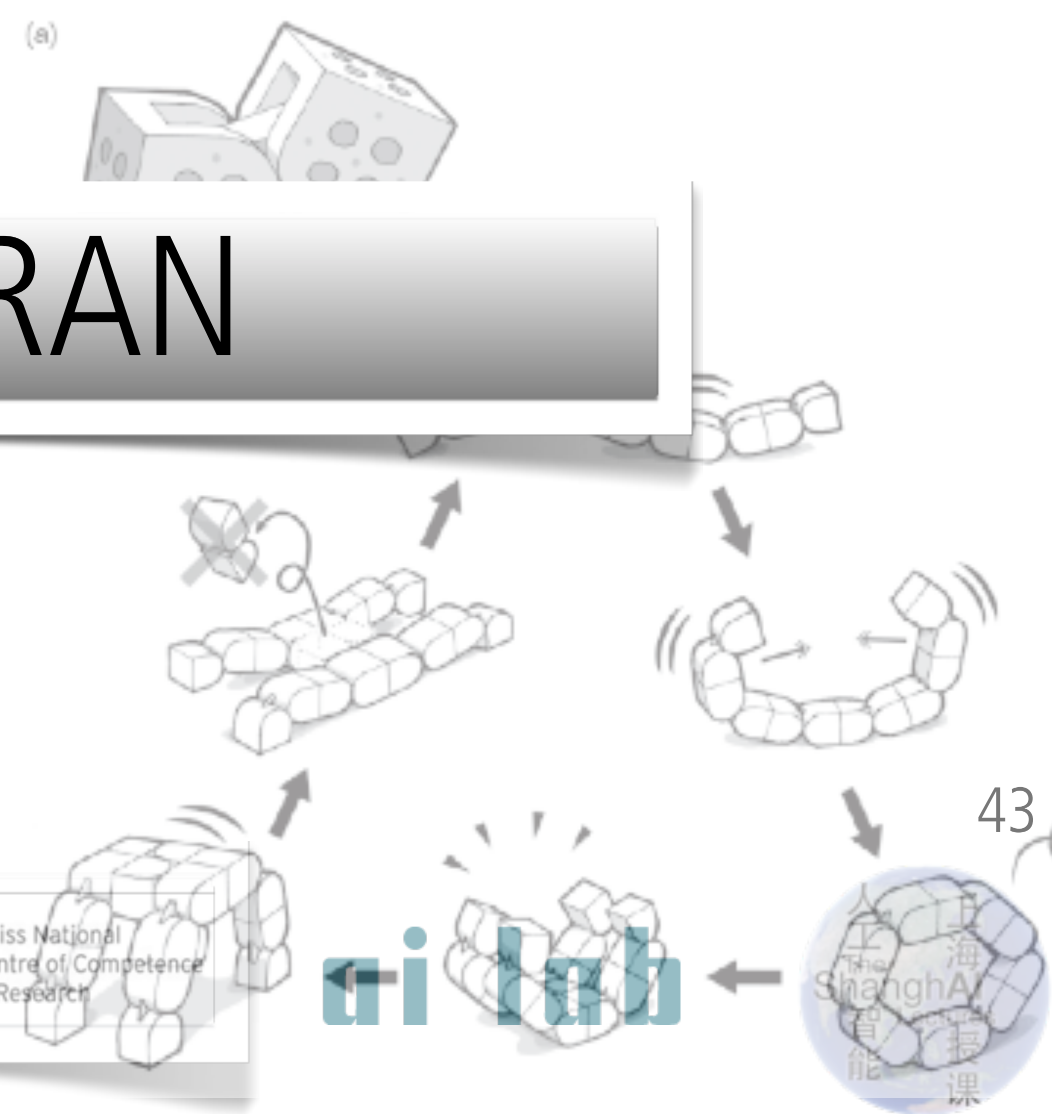
- 10cm scale
- morphing through local interaction (no external intervention required)
- individual actions centrally calculated by evolutionary methods
- emergence: matter of degree



Emergence is always a matter of degree. The more you back off on your designer commitments, the more there is room for emergence, but the harder it will be to achieve a specific functionality. The fewer designer commitments, the more the characteristics of the agent will be its own rather than the ones of the designer, which also implies that the agent will be more autonomous.
In the M-TRAN case we can ask the question to what extend its behavior is emergent.

Modular robotics
Satoshi Murata's M-TRAN

- 10cm scale
- morphing through local interaction (no external intervention required)
- methods
- emergence: matter of degree



Video: M-TRAN

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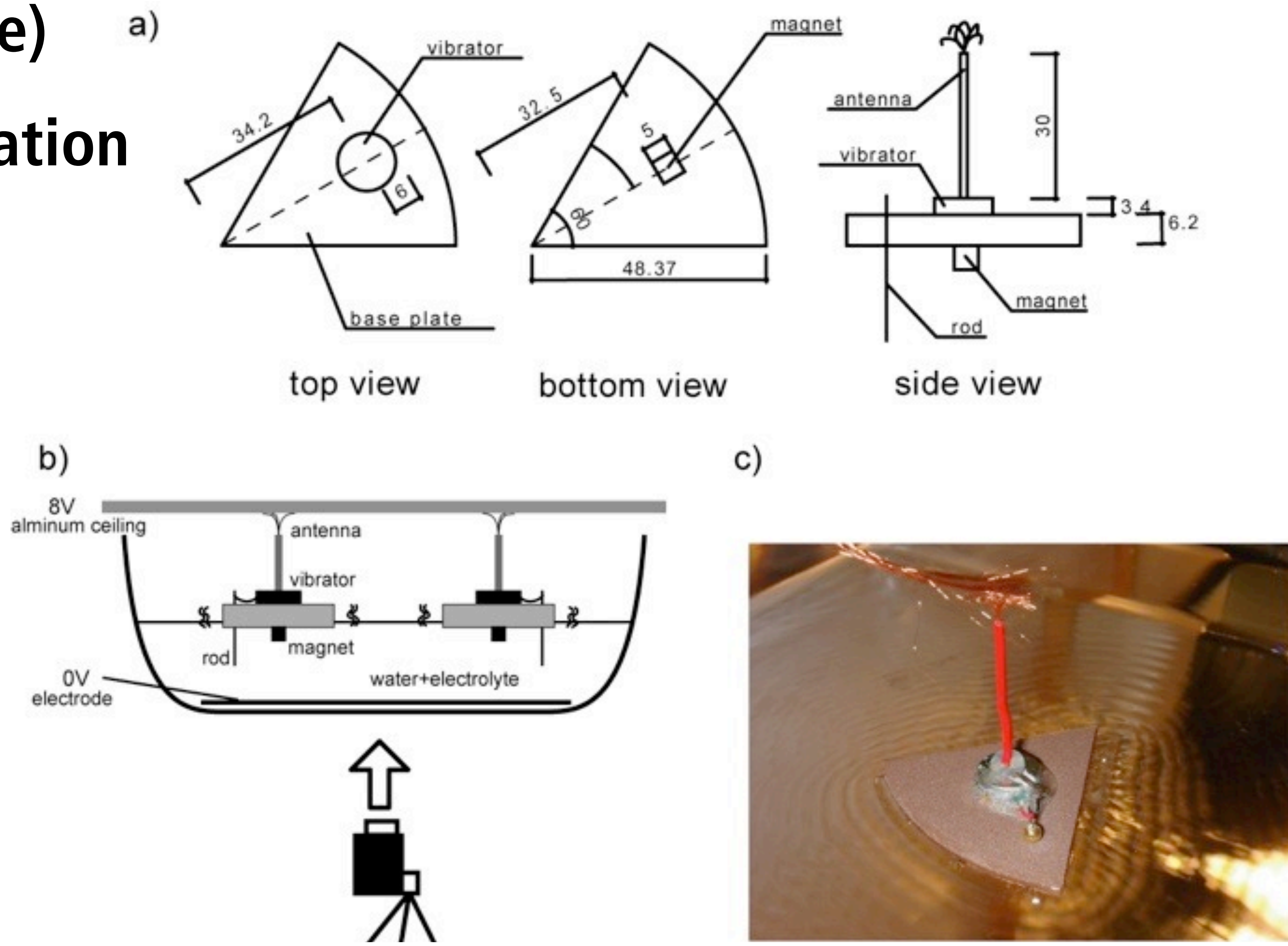
Self-assembly

- **collection of modules**
- **spontaneous structure formation**
- **emergent functionality**

Self-assembly
Shuhei Miyashita's "Tribolons"

- **light, swimming on water (electrolyte)**
- **magnet and vibration motor**
- **"pantograph"**



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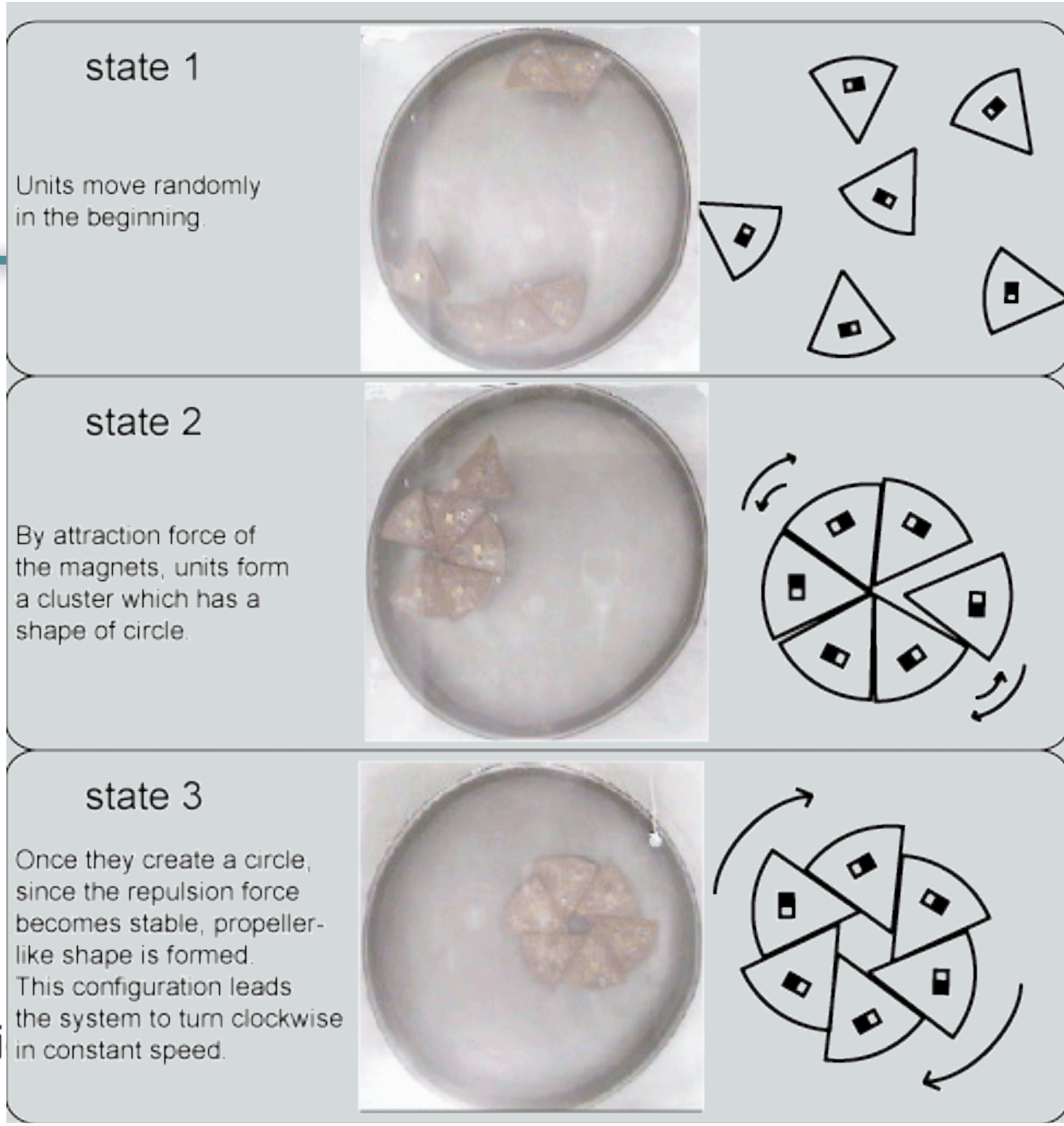
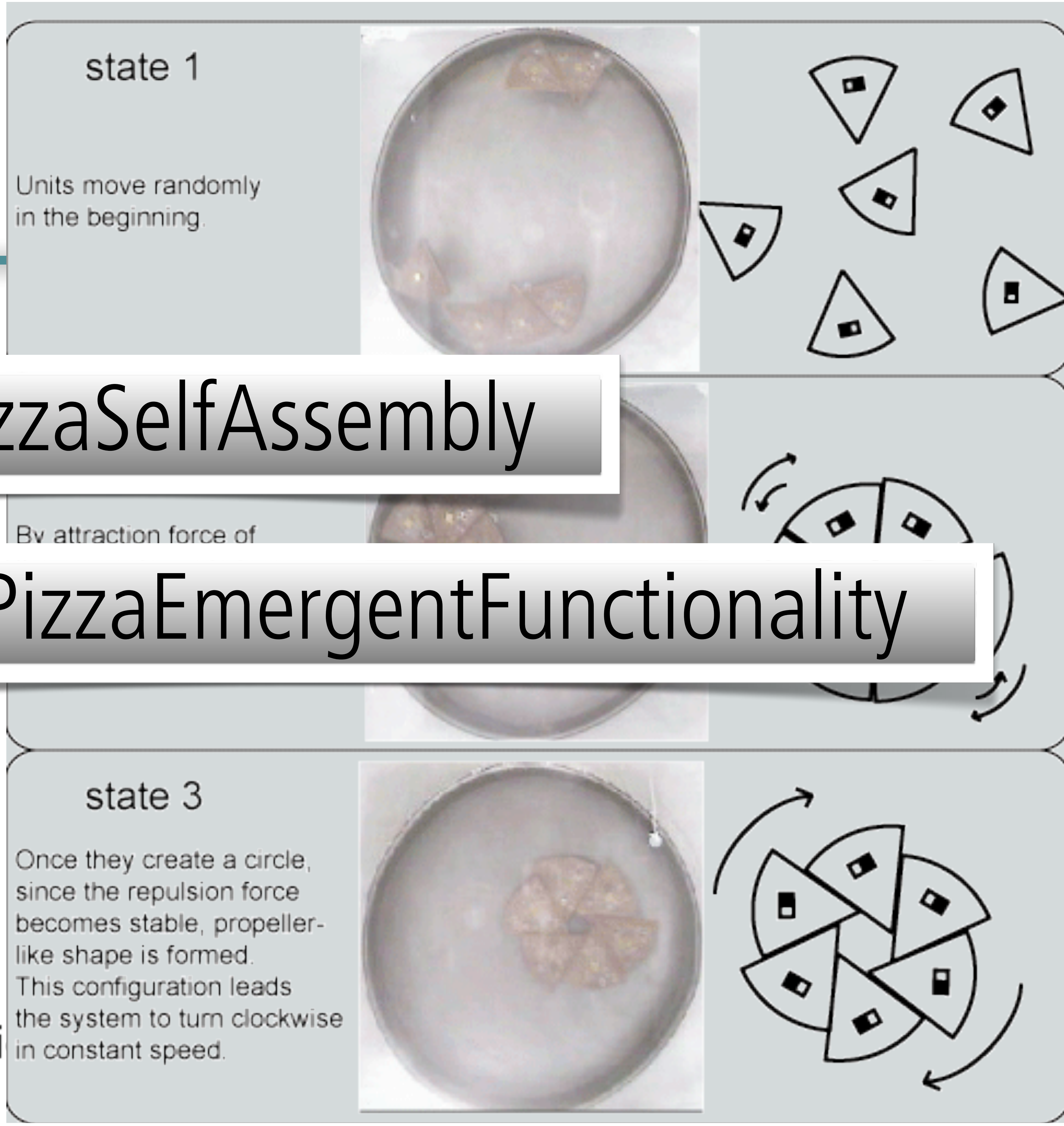
The "Tribolons" are light-weight swimming tiles equipped with a vibration motor - to provide non-specific energy - and a magnet. There is no microprocessor and therefore, in the classical sense, no "control".

“Pizza” self-assembly



"Pizza" self-assembly



Video: PizzaSelfAssembly

Video: PizzaEmergentFunctionality

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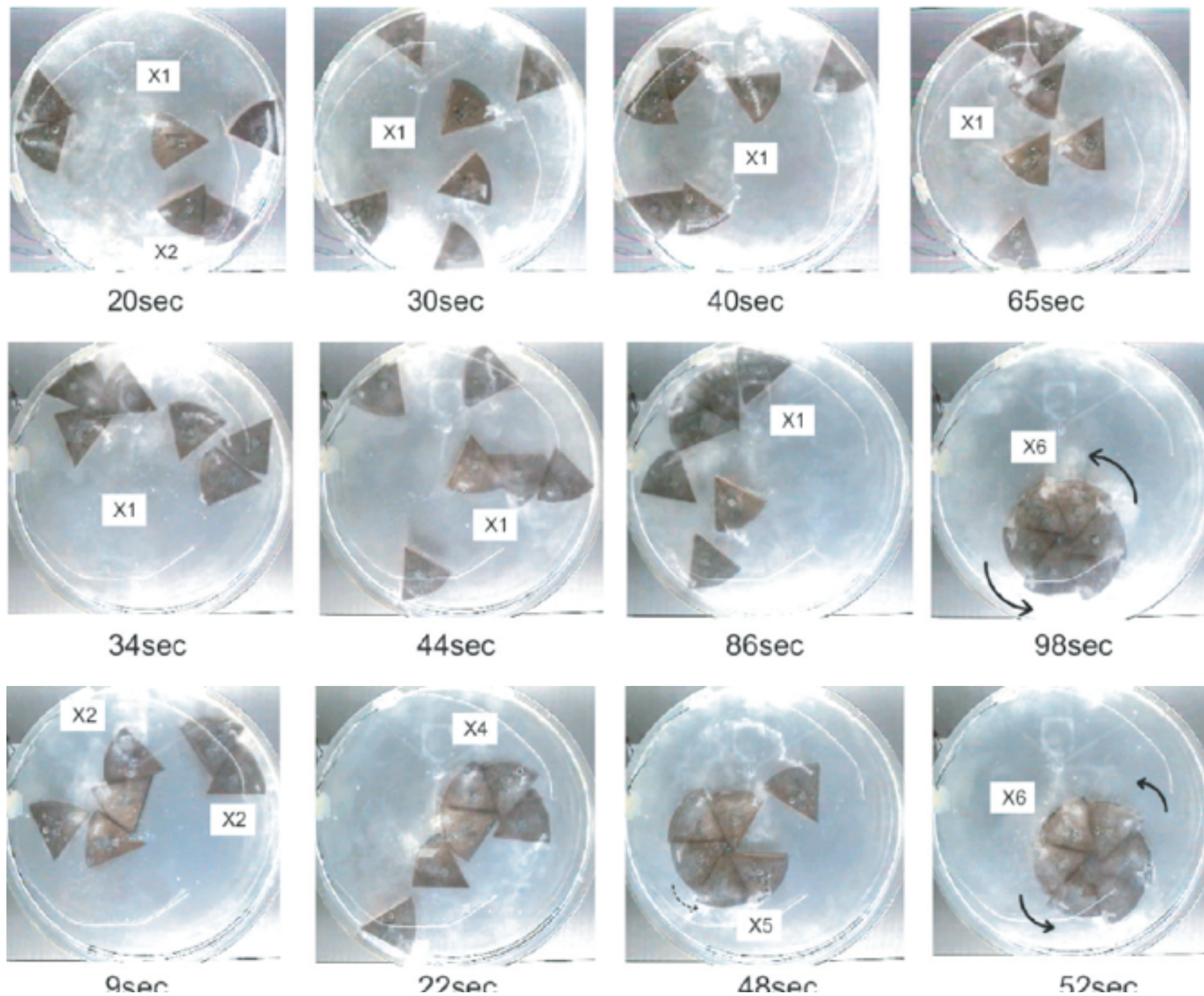
In this example, there is emergent functionality. Even though the individual tiles don't rotate, the structure as a whole will. As can be clearly seen from the videos, the global structure is the result of a dynamic equilibrium, i.e. the structure is continuously moving.

Self-assembly
Dependence on energy levels

9 volt:
random movement

8 volt:
one-shot self-assembly
(low probability)

7 volt:
incremental self-assembly
(high probability)



in this example, at high voltages, there is no self-assembly. At intermediate levels of energy input, there is a low probability of "one-shot" self-assembly, i.e. all tiles have to meet simultaneously in order for the structure formation to occur. At low evergy input (7 volts), stable sub-structures form which strongly increases the probablity of global structure formation.

Emergent functionality
a "bicycle"

emergent functionality (not self-assembly)

yellow triangle: vibration motor and magnet

green discs: only magnet, passive

Video: bike4.mov

how does it work?

Design and construction
Shuhei Miyashita

Emergent functionality
a "bicycle"

emergent functionality (not self-assembly)

yellow triangle: vibration motor and magnet

green discs: only magnet, passive

How does it work?
speculation?

—> Karlsruhe

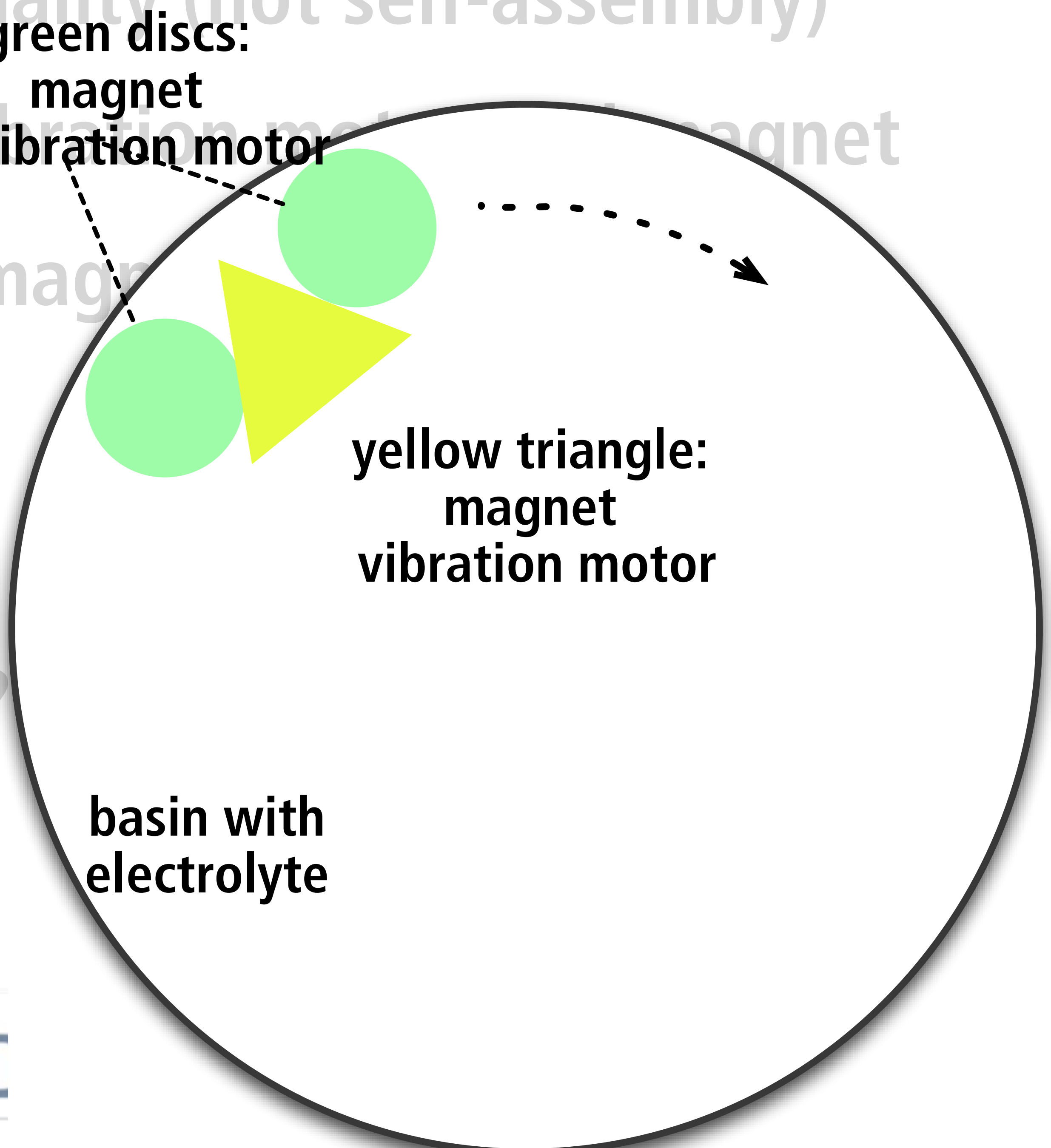
Emergent functionality a “bicycle”

emergent functionality (not self-assembly)

yellow triangle: vibration mo agnet

green discs: only magn

how does it work?



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The vibrations of the triangle are propagated to the passive green discs, which then cause the entire structure (held together by the magnets) to follow the wall of the container. This is an interesting case study demonstration the need to build actual physical robots. It is doubtful that any of the state-of-the-art simulators would have delivered this result.

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

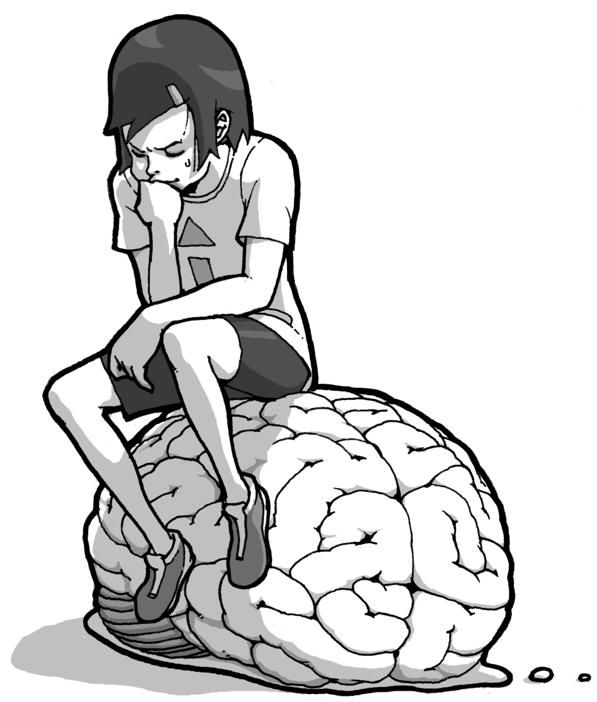
- Read chapter 7 of "How the body …"
- Additional slide materials for self-study
- Think about how to design a simulation model for flocking from a situated perspective (following up on the suggestions from Shanghai)

End of lecture 7

Thank you for your attention!

stay tuned for lecture 8

“Where is human memory”



Stay tuned for guest lectures

Lecture 7: Guest speaker

from Budapest

István Harmati, Budapest Univ. of Technology and Economics
"Coordination of multi-agent robotic systems"

10.00h Zurich time

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Lecture 7: Guest speaker

from Abu Dhabi

Prof. N. Mavridis, with Ibn Sina

Nikolaos Mavridis, NYU (New York University), Abu Dhabi Campus
“The human-robot cloud: Towards situated collective large-scale human-machine intelligence”

10.30h Zurich time

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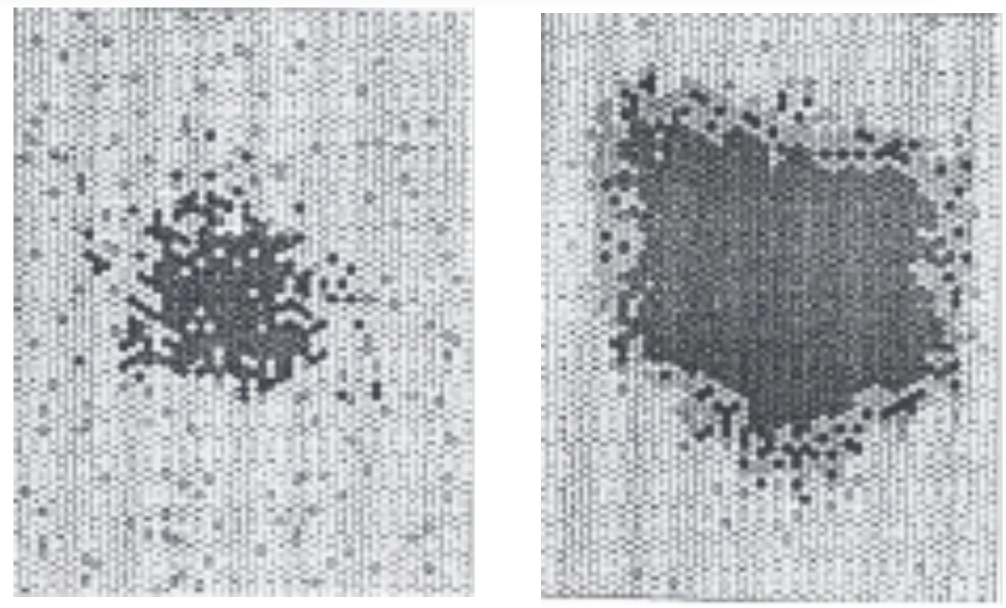
Additional slide materials for self-study

Honey bees: Self-organization in a “super-organism”

1. **Deposit brood in cells next to cells already containing brood**
2. **Deposit nectar and pollen in arbitrary cells, but extract both products preferably from cells closest to the brood**
3. **Extract pollen with higher probability than nectar**



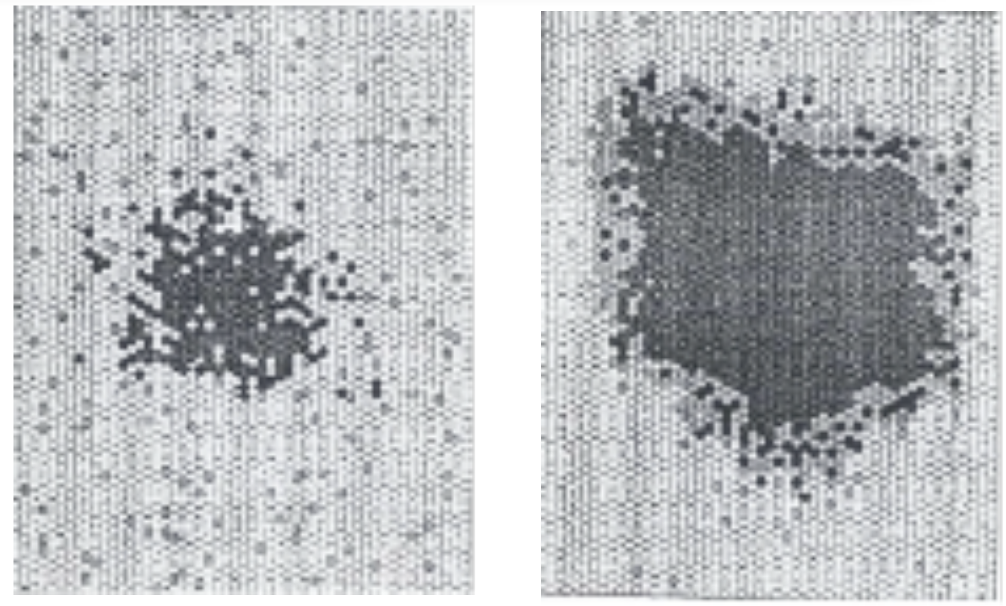
Simulation data: Camazine et al., Cornell University

following local rules → global patterns (emergence)

There is a frame-of-reference problem (see David McFarland: “Anthropomorphization, the incurable disease”): such collective organisms have amazing abilities. We have to be careful not to attribute too many cognitive abilities to them. Here is how the pattern formation works:
The distribution of brood and nourishment in the comb of honey bees is not random, but forms a regular pattern, which is organized in such a way, that the central brooding region is close to a region containing pollen and one containing nectar (providing protein and carbohydrates for the brood). Despite the fact that, due to the intake and outtake of pollen and nectar, this pattern is changing all the time on a local scale, observed from a more global scale, the pattern stays stable. By performing experiments, it has been discovered that this is not the result of an individual bee being aware of the global pattern of brood and food-distribution in the comb, but of three simple local rules, which each individual bee follows. Please note, that the individual bee does not know whether and how the cells of the comb are filled with nectar and pollen, but it only follows the three simple rules stated above. In other words, these three rules are sufficient to create the global pattern.

Honey bees: Self-organization in a "super-organism"

1. **Deposit brood in cells next to cells already containing brood**
2. **Deposit nectar and pollen in arbitrary cells, but extract both products preferably from cells closest to the brood**
3. **Extract pollen with higher probability than nectar**



Simulation data: Camazine et al., Cornell University

following local rules →
global patterns (emergence)

(taken from an article by Ruediger Wehner (1998). Self-organization in a super-organism. Collective intelligence of social insects
(in German: Selbstorganisation im Superorganismus. Kollektive Intelligenz sozialer Insekten), Zurich, NZZ Forschung und Technik, 14. Januar 1998, 61.)

Agent-based modeling

- "digital social science toolbox" by Josh Epstein and Robert Axtell ("Growing artificial societies: Social sciences from the bottom up", MIT Press, 1996)
- origin: Schelling's model of segregation (see "How the body …", pages 217-218)

Schelling's model consists of a 2-d grid on which red and blue agents "live". They have preferences. For example, if the number of neighbors of the same color is below 25%, they move randomly to a new position. In this case, the simulation shows that there is already some pattern of segregation emerging. If the preferences are assigned randomly to agents between 25 and 50% (i.e. they will move if the percentage of neighbors of the same color drops, e.g. below 29% or 42%, they will move), strong patterns of segregation will emerge. This is surprising because even though the preferences of the individuals are very mild and can hardly be called racist, at the global level, there is a highly segregated society. The message from this is that it is hard to draw inferences about individual preferences by merely observing the global patterns
(Schelling,T.C. (1969). Models of segregation. American Economic Review (Papers and Proceedings), 59(2): 488–493).
Agent-based modeling has become very popular, especially in the artificial life community.

End of additional materials for self-study