人工智能 The ShanghAI Lectures 上海授课

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

Today from the University of Zurich, Switzerland
Shanghai Jiao Tong University, China
Karlsruhe Institute of Technology, Germany
University of Reading, UK
Sussex University, UK

15 December 2011

欢迎您参与

“来自上海的人工智能系列讲座”

Future trends: Schedule

with world class guest lecturers - the super-cracks:

09.00 - 09.20 Rolf's introduction: Seeing things differently

09.20 - 09.50 Weidong Chen, Shanghai Jiao Tong University, China

09.55 - 10.20 Ruediger Dillmann, Karlsruhe Institute of Technology, Germany

10.25 - 10.55 Kevin Warwick, University of Reading, UK

11.00 - 11.30 Inman Harvey, University of Sussex, UK

11.30 Rolf: Final comments

moderator:

Rolf Pfeifer, University of Zurich, Switzerland

Seeing things differently
a few illustrations

Seeing things differently

- “Cleaning up”, the “Swiss robots”
- Walking without control
- Rapid locomotion with slow electronics
- Coordination through interaction with world
- Social interaction as “reflexes”
- Optimization without cognition
- Creative computers

Activities involved in clustering: standard solution

6x6m arena with Styrofoam cubes

- Look for cube, if possible, the nearest one.
- Pick up cube (somehow).
- Look for nearest cluster.
- Go to cluster.
- Deposit cube.
- Look for new cube, etc.

→ sophisticated perceptual skills required

Look for cube, if possible, the nearest one). Pick up cube (somehow). Look for nearest cluster. Go to cluster. Deposit cube. Look for new cube, etc.
Requires quite sophisticated perceptual skills on the part of the robots (recognizing a cube from different angles and distances, recognizing a cluster). Some elementary motor skills for grasping and dropping. locomotion skills.

The solution: simple rules

behavioral rule:

sensory stimulation on left: turn right

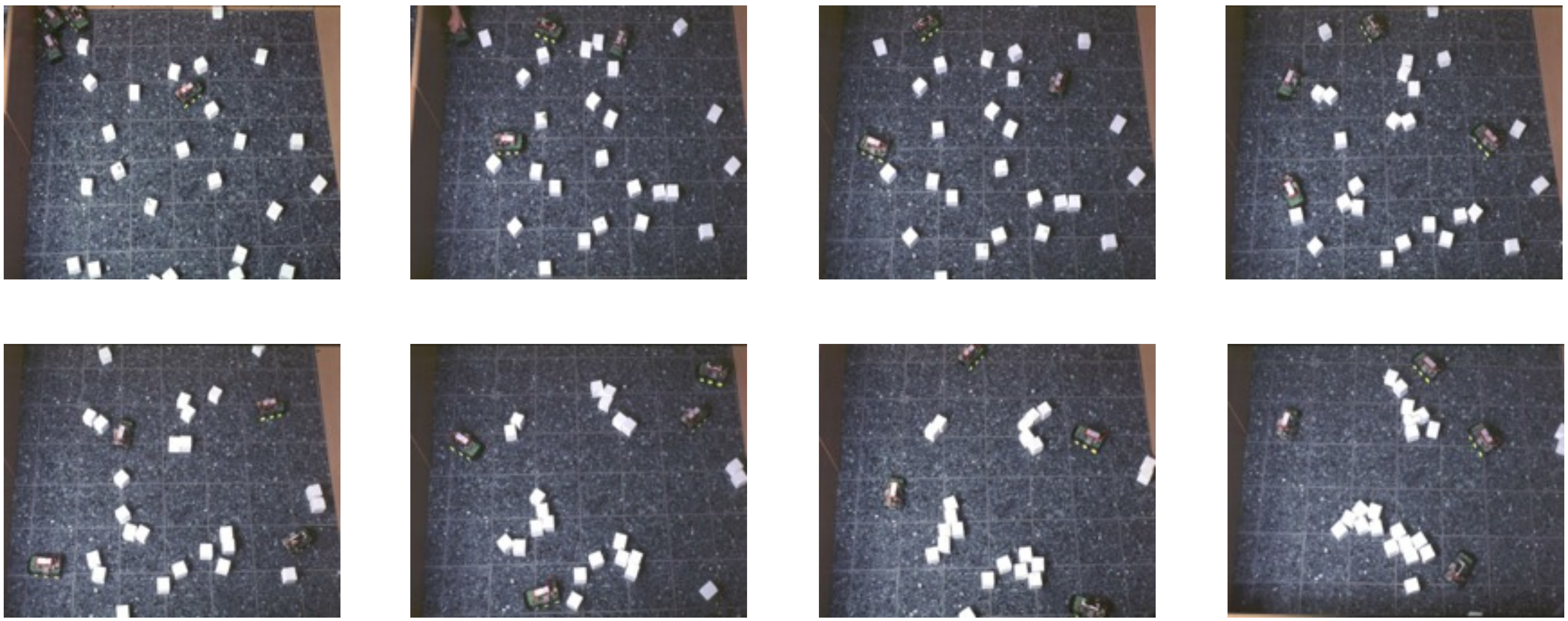
sensory stimulation on right: turn left

(obstacle avoidance)

→

situated perspective (from the agent's point of view)

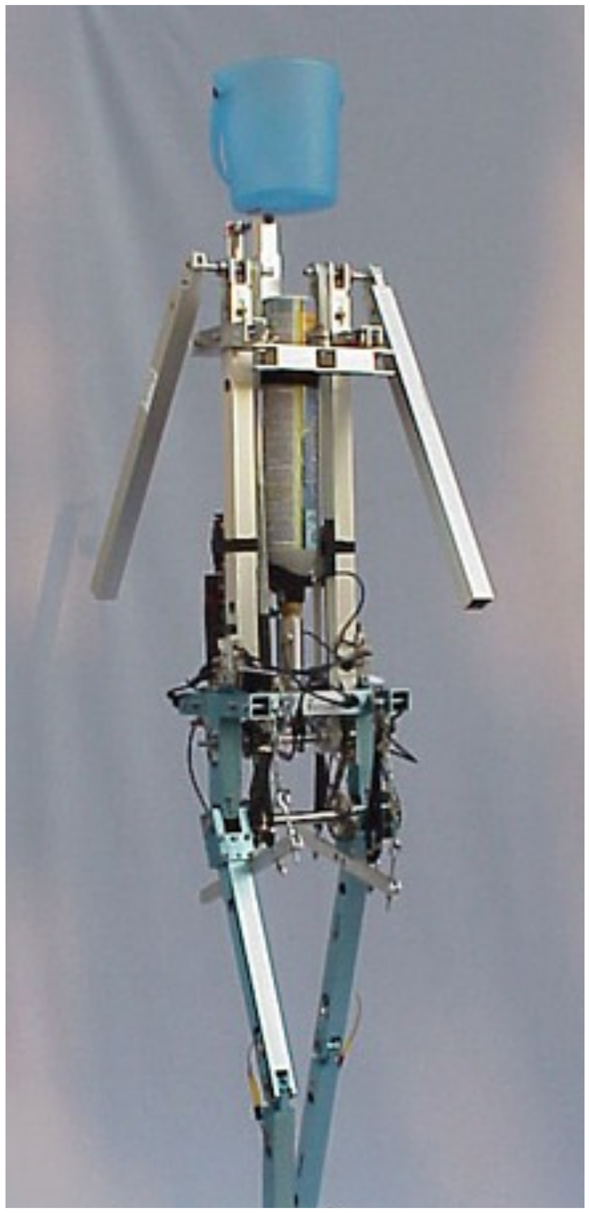
Design for emergence: cleaning an arena



entire process: ～20min
frames: 2-3min

Walking without control?

The solution:
The “Passive Dynamic Walker”

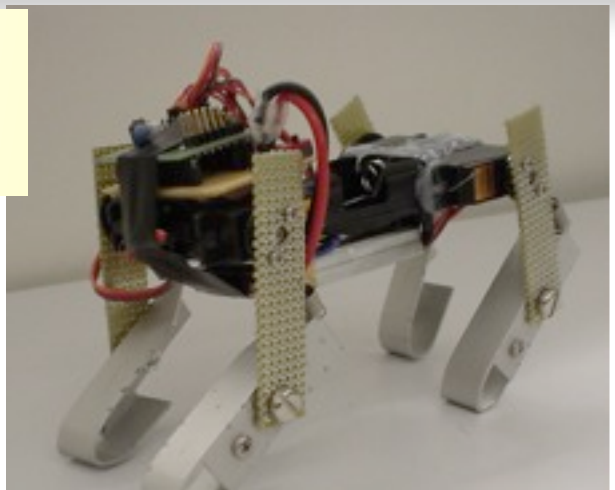


“Denise”
no control for balance

Rapid locomotion with slow electronics/brains?

The solution: "Exploitation of morphology and materials"

"Puppy"

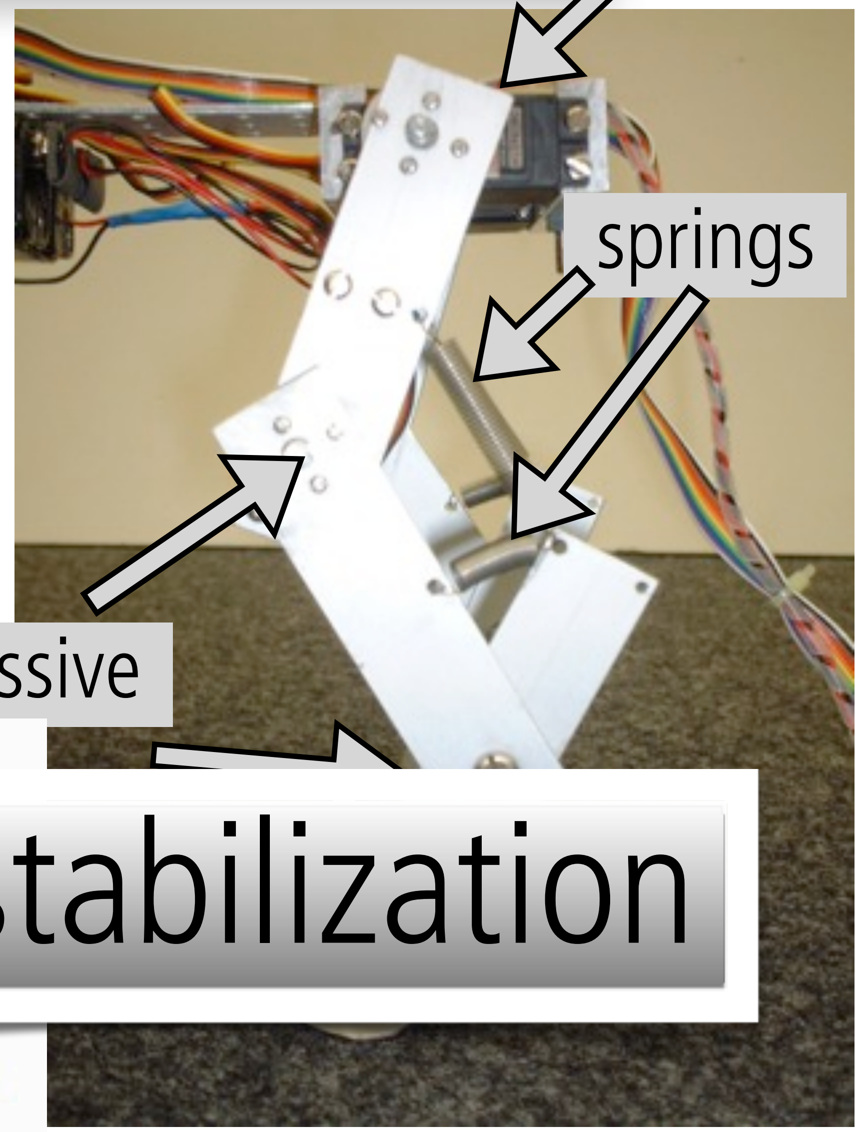


morphological computation

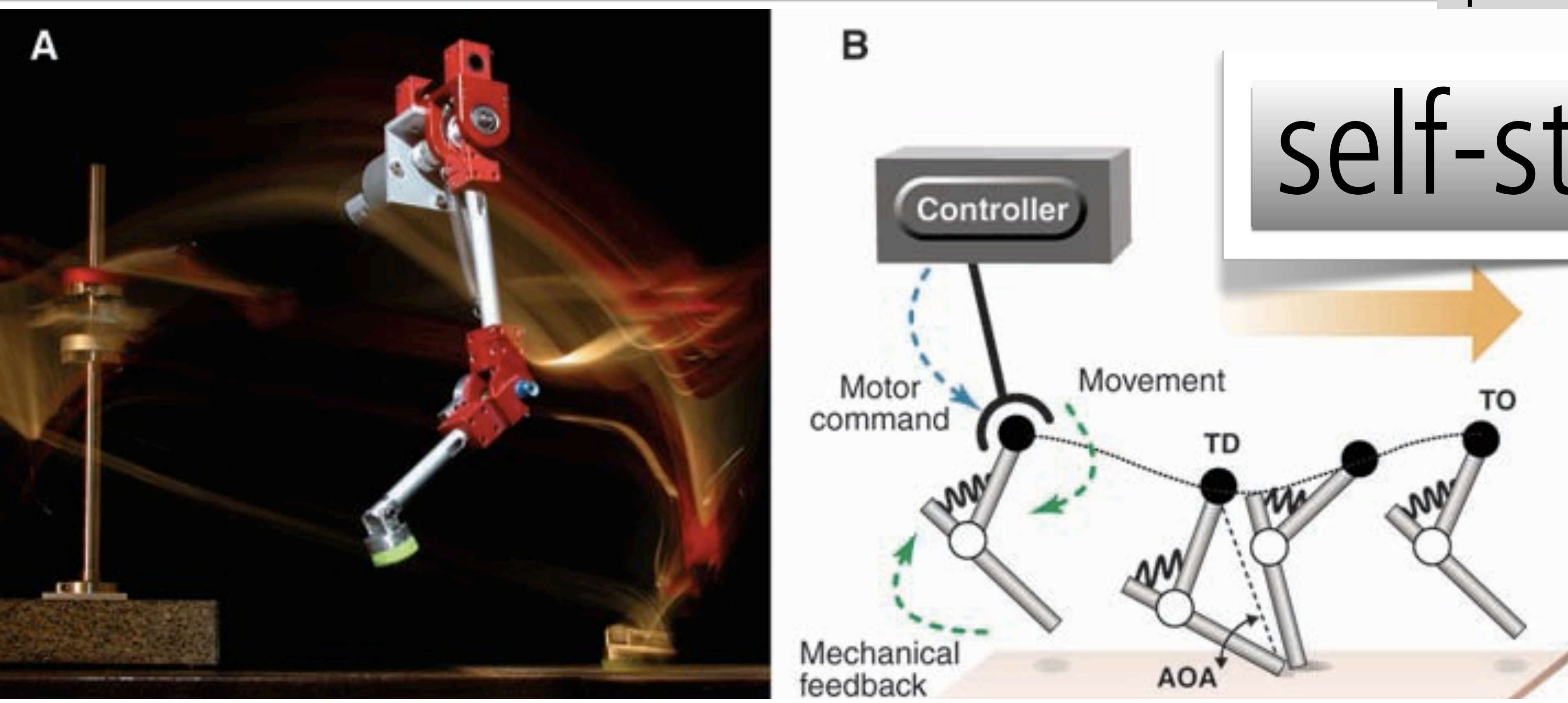
actuated: oscillation

springs

passive



self-stabilization



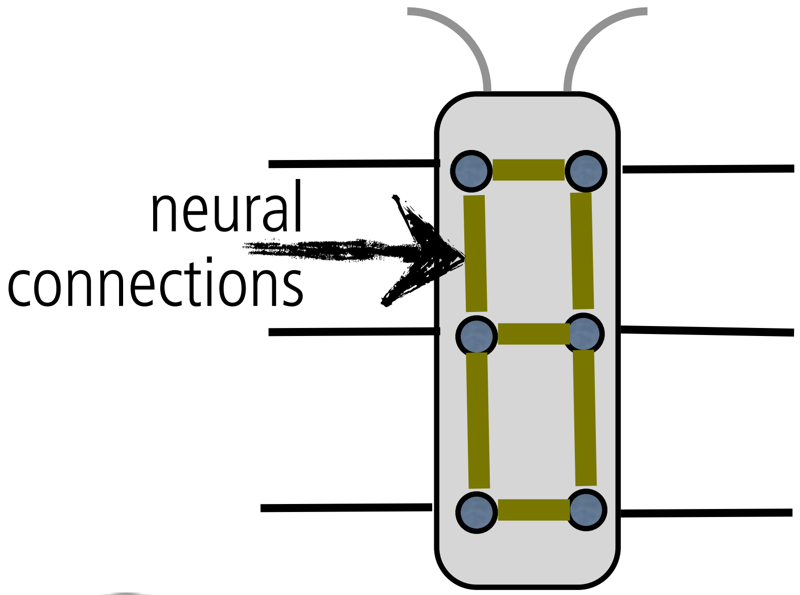
Jena monoped

Leg coordination without central control?

Parallel, loosely coupled processes

Holk Cruse, German biologist

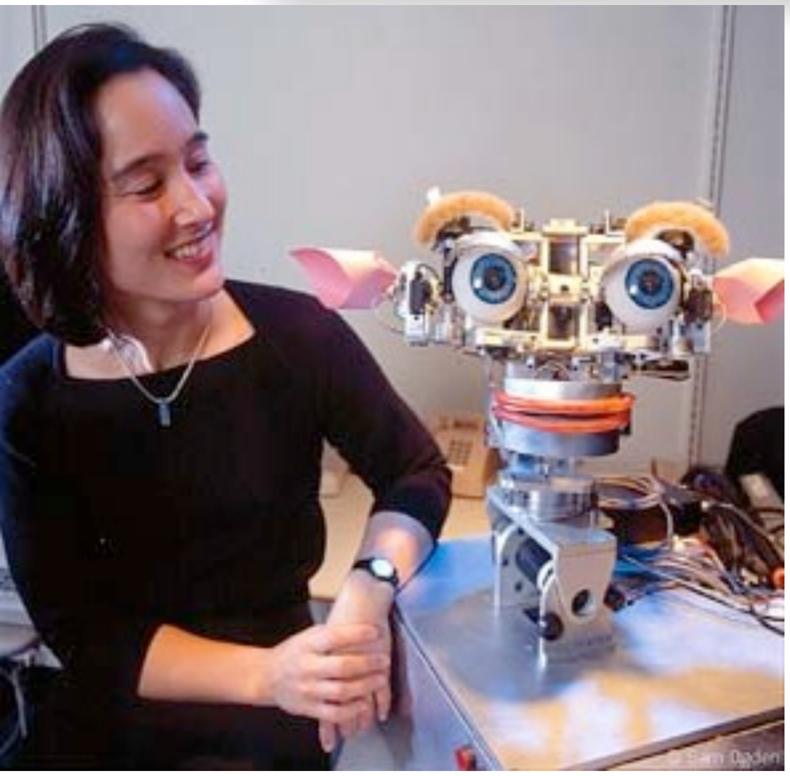
- **no central control for leg coordination**
- **only communication between neighboring legs**
- **global communication/coupling: through interaction with environment**



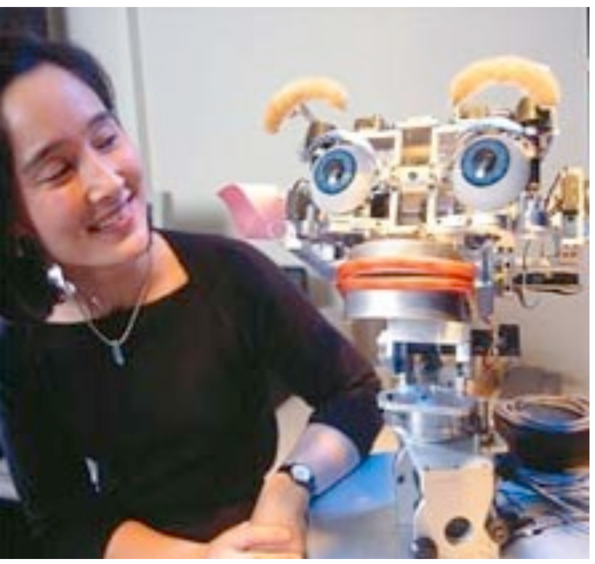
There are two aspects to this case study. First, because the insect is a physical system, if one leg pushes backwards, all the other legs will be moved as well, i.e. the joint angles will change. Second, because every action - in this case the pushing back of the leg - has a consequence in terms of patterns of sensory stimulation induced - which leads to a change of the joint angles - there is global communication between the legs, through the interaction with the environment. And this communication can be exploited for leg coordination.

Social competence without high-level cognition?

Social competence without high-level cognition?



Cynthia Breazeal, MIT Media Lab



reflexes:

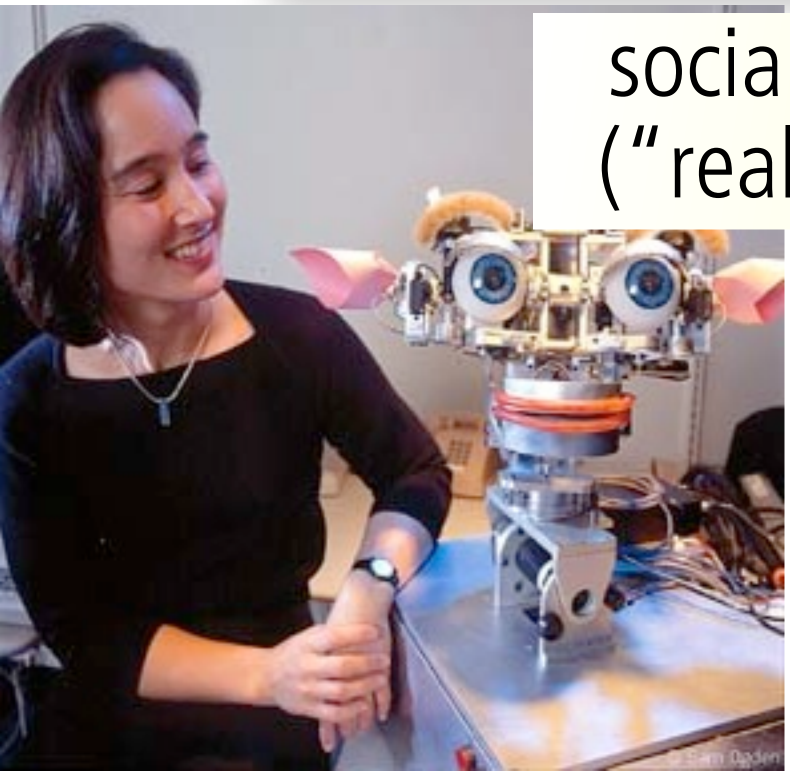
turn towards sound

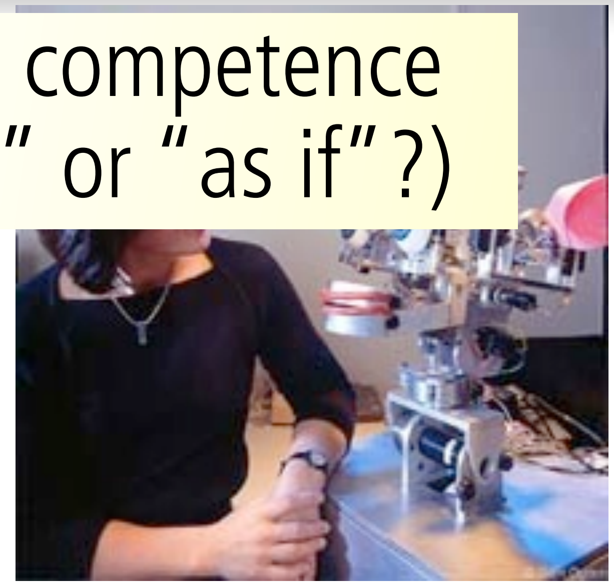
turn towards moving objects

visual tracking of slow objects

habituation

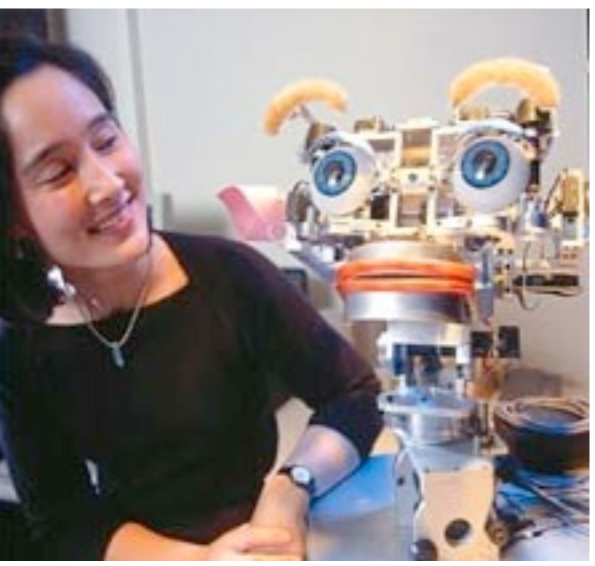
Social competence without high-level cognition?





social competence
(“real” or “as if”?)

Cynthia Breazeal, MIT Media Lab



reflexes:

turn towards sound

turn towards moving objects

visual tracking of slow objects

habituation

Rodney Brooks, MIT:
“What do you mean — ‘as if’? This **IS** social competence”

Social behavior through simple reflexes?

John Bargh, Psychologist, Yale Univ.
"The unbearable automaticity of being", 1999

Finding shortest paths without measuring, storing, comparing?

Optimization without cognition
Parallel, loosely coupled processes

coupling through pheromone trails
in environment

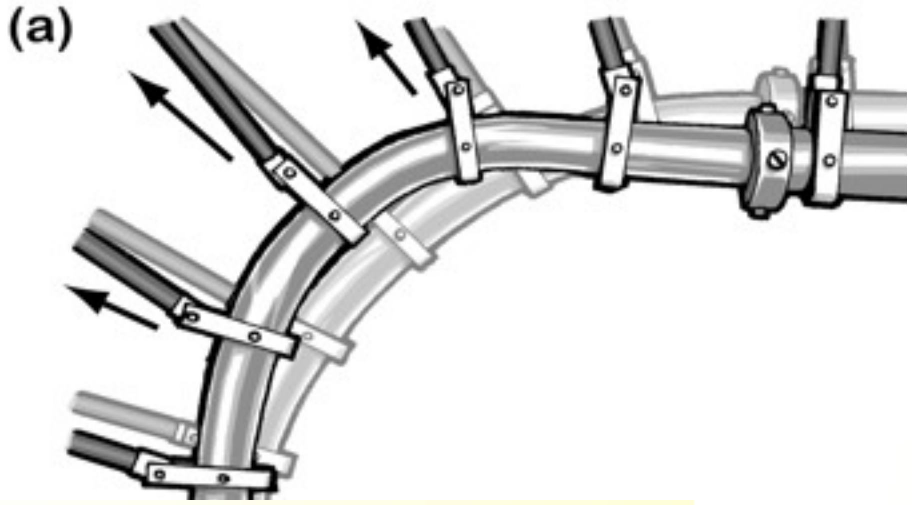
Pheromone trails enable ants to search for food efficiently: Two ants leave the nest at the same time (top), each taking a different path and marking it with pheromone. The ant that took the shorter path returns first (bottom). Because this trail is now marked with twice as much pheromone, it will attract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

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

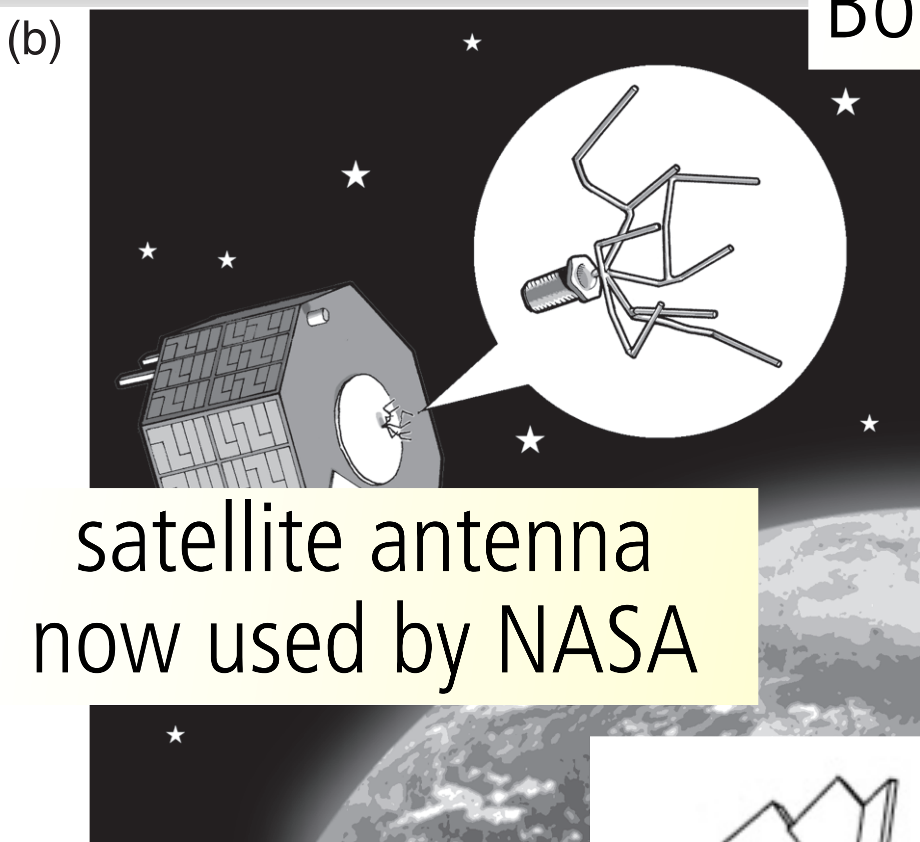
Creative computers, robots?

- "Computers can never be creative — they can only reproduce what you program into them"
- From the movie "I, Robot". Human to robot (my transcription): "Robots could never be creative, they could never write a symphony like Beethoven!" Robot to human: "Could you?"

Solution: Artificial evolution and morphogenesis

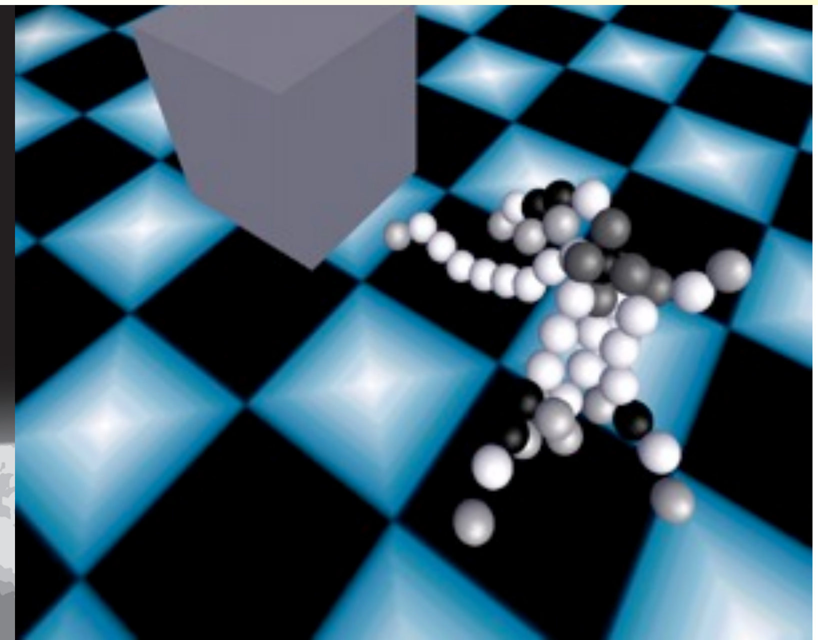


Rechenberg's 'hunched" fuel pipe solution

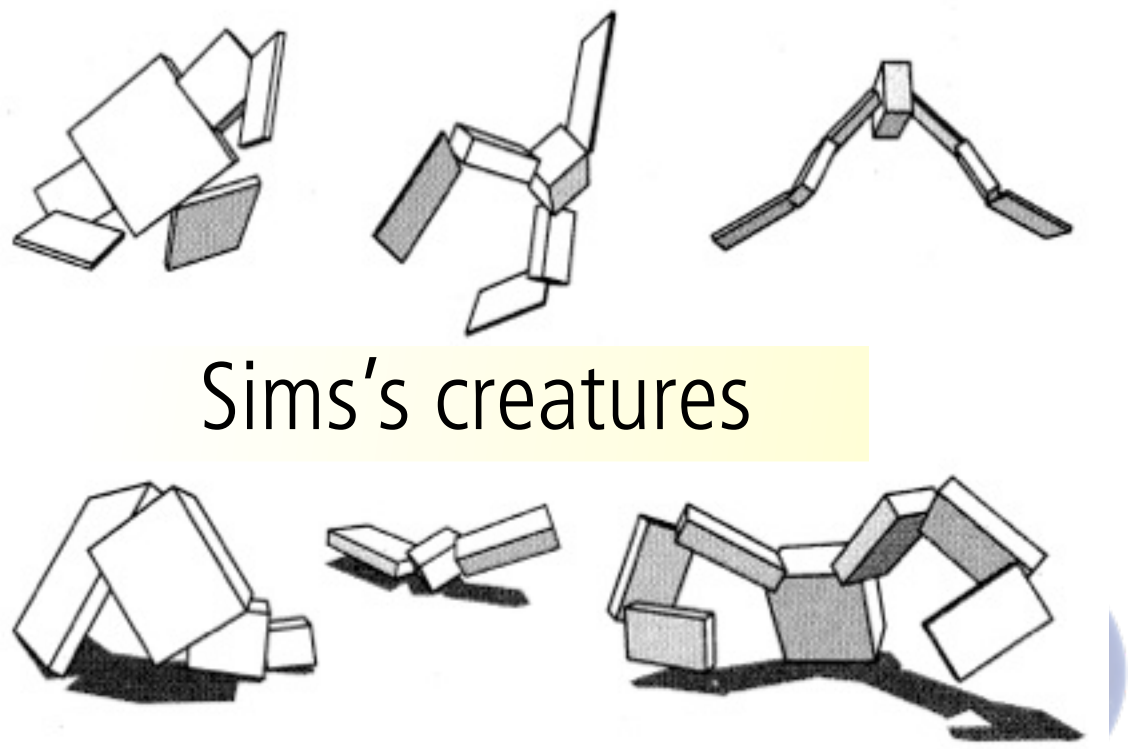


satellite antenna now used by NASA

Bongard's "Block Pushers"



Lipson's creatures "Golem" project



Sims's creatures

GAs come up with solutions that humans, at least until to date, have not been able to find.

That's it!

Thank you for your attention!

stay tuned for

Chen, Dillmann, Warwick, Harvey

Weidong Chen: Guest speaker

Department of Automation
School of Electronic, Information, and Electronic Engineering
Institute of Robotics and Intelligent Information Processing
Shanghai Jiao Tong University
Shanghai, China

Prof. Weidong Chen
"Enhancing autonomy and safety of assistive robots"

First host of ShanghAI Lectures, 2009

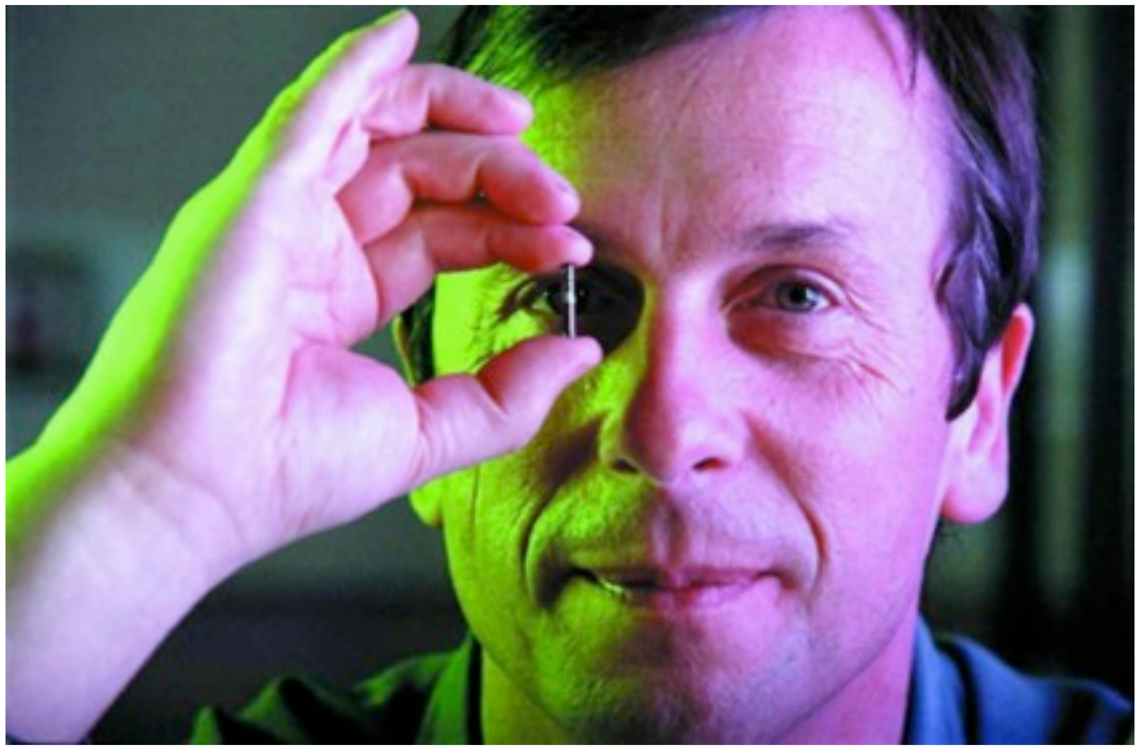
Ruediger Dillmann: Guest speaker

Institute of Anthropomatics,
Karsruhe Institute of Technology
Germany

Prof. Ruediger Dillmann
"Programming by demonstration"

"Mr. Robotics, Germany"

Kevin Warwick: Guest speaker



Professor of Cybernetics
University of Reading
"Mr. Cyborg"

Prof. Kevin Warwick, University of Reading, UK
"AI with biological brains"

Inman Harvey: Guest speaker

Sussex University, UK

Inman Harvey
"Metaphorical Homunculi: we don't really have little men in our heads"

Epilogue

David Payne *Confessions of a Taoist on Wall Street*
Sun I: little boy growing up in monestary
Wu: chef (cook) of monestary and Sun I's mentor

The little boy, Sun I, is born of a Chinese mother and an American fighter pilot in China. His mother dies at birth and his father returns home to the United States; he is left alone and grows up in a monastery. His mentor and teacher is the chef, Wu, who takes good care of him. The monastery is on a high rock upon a river. One of their daily chores is to carry water from the river to the monastery up a rocky path. The boy remembers that whenever they arrived at the top of the rock his buckets were empty, all the water spilled, whereas Wu's were always full.

Yoke with water buckets

Courtesy Purdue University Libraries, Archives and Special Collections

Conversation between Sun I and Wu

It was true. By some extraordinary luck or skill Wu never seemed to lose a drop, though he hurried along the treacherous stair at twice my pace. (I tried to cut my losses by moving slowly, plotting my course in advance and picking each footrest with deliberate care.)

"I don't understand it," I confessed to him. "You must know some kind of trick. Explain your method." ...

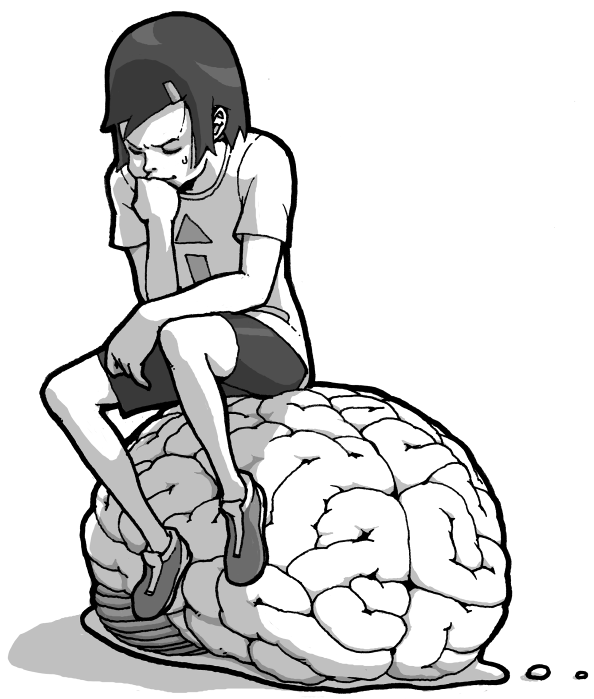
"You haven't yet caught on. It's precisely this—excess of method—that confounds you, leaves the buckets nearly empty …"

"If you're so smart, how do you do it then?"

"How do I do it? . . . I close my eyes and think of nothing. My mind is somewhere else. My legs find their way without me, even over the most uneven ground. How can I tell you how I do it? . . . I can't even remember myself!" (Payne, 1984, pp. 18–19)

End of Future Trends Session

Thank you for your attention and thanks to all the speakers!



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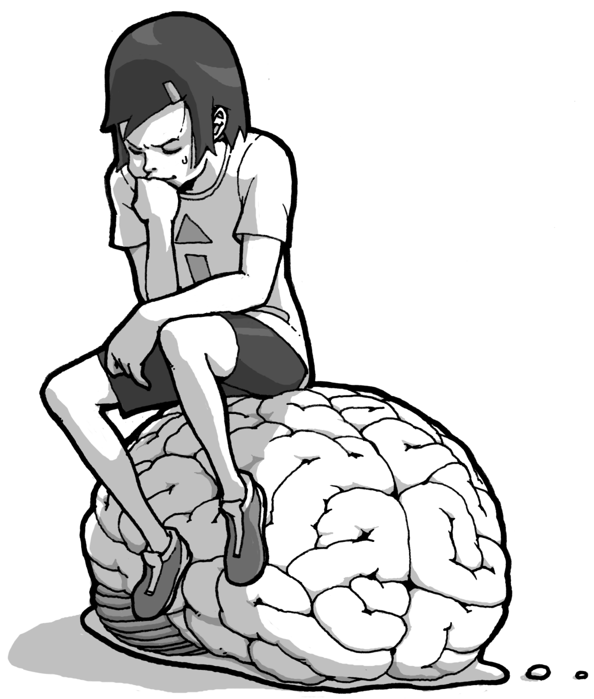
End of Future Trends Session

Thank you, participants, technicians, all who have helped, and thank you Nathan!!



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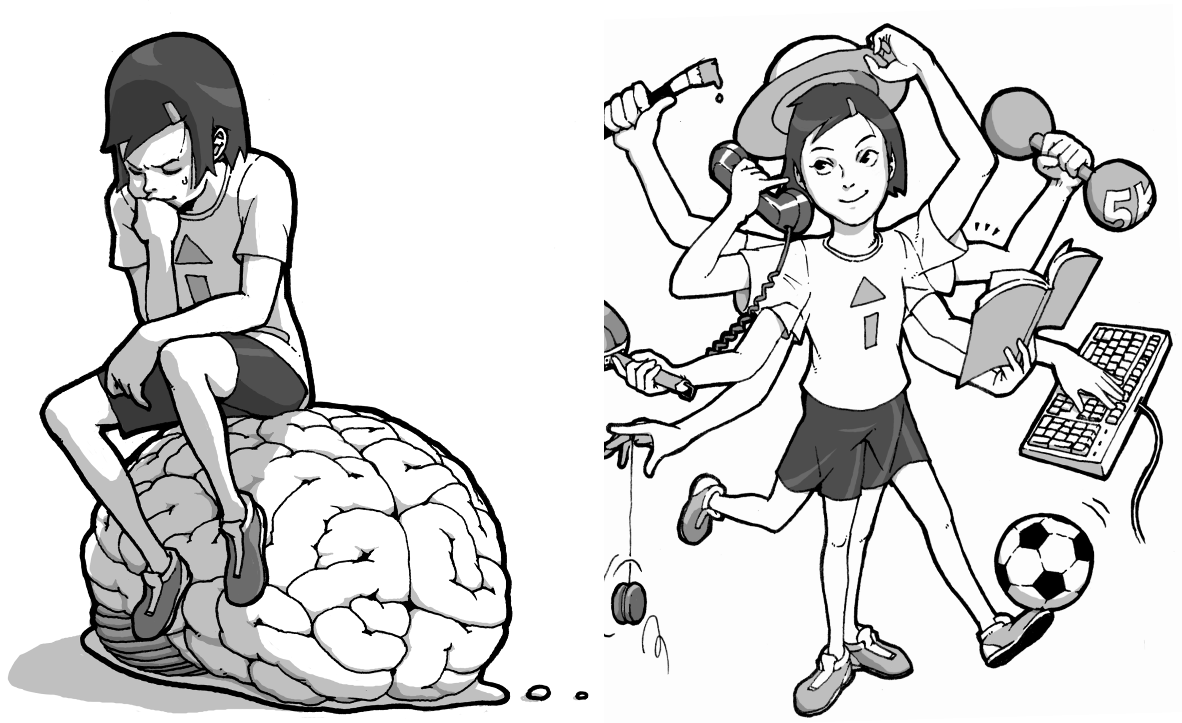
The future of the ShanghAI Lectures

Join our discussion about the future of the ShanghAI Lectures - your input is extremely valuable and warmly appreciated!



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The ShanghAI Lectures
人工智能上海授课

Additional materials for self-study

- Steps toward a theory of intelligence
  - “Mind set”
  - Properties of real world and embodied agents
  - Design principles
- Design principles for intelligent systems
- Epilogue

Steps toward a theory of intelligence

1. Meta-considerations: “Mind Set”
2. Properties of physically embodied agents and of real world
3. Design principles

Steps toward a theory of intelligence

1. **Meta-considerations: “Mind Set”**
2. Properties of physically embodied agents and of real world
3. Design principles

Steps toward a theory of intelligence

- level of generality and form of theory
- diversity-compliance
- frame-of-reference
- synthetic methodology
- time perspectives
- emergence

Steps toward a theory of intelligence

- **level of generality and form of theory**
- diversity-compliance

design principles
theory of complex dynamical systems

- time perspectives
- emergence

Steps toward a theory of intelligence

- level of generality and form of theory
- **diversity-compliance**

here-and-now: comply/exploit—diversity
learning: plasticity—stability trade-off
evolution: exploration—exploitation

Steps toward a theory of intelligence

- level of generality and form of theory
- diversity-compliance
- **frame-of-reference**
- synthetic methdology
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- emergence

Steps toward a theory of intelligence

- level of generality and form of theory
- diversity-compliance
- **frame-of-reference**
- s
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- e

perspective
behavior vs. mechanism
complexity

Steps toward a theory of intelligence

- level of generality and form of theory
- diversity-compliance
- frame-of-reference
- **synthetic methodology**
- time perspectives
- emergence

Steps toward a theory of intelligence

- level of generality and form of theory
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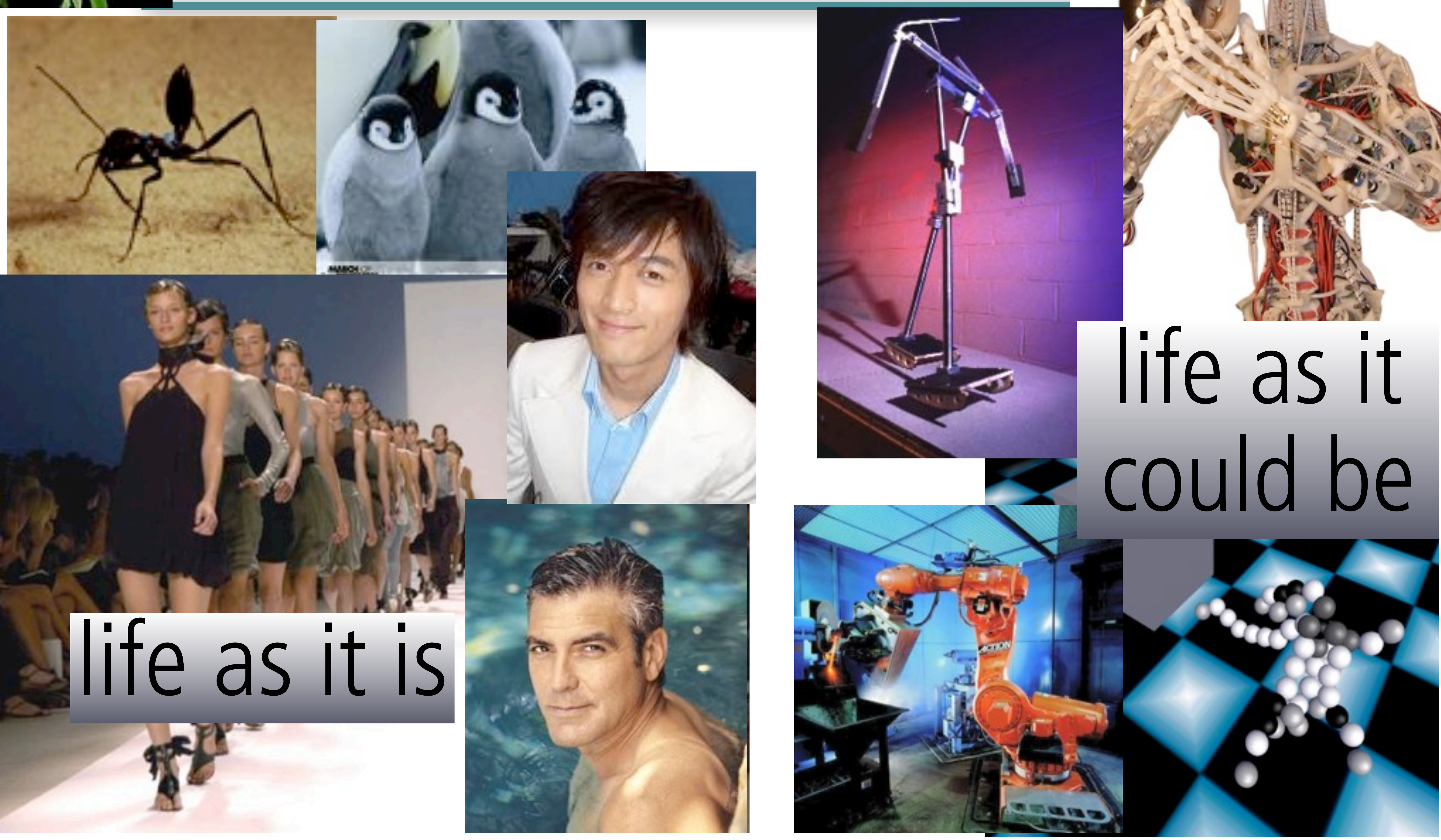
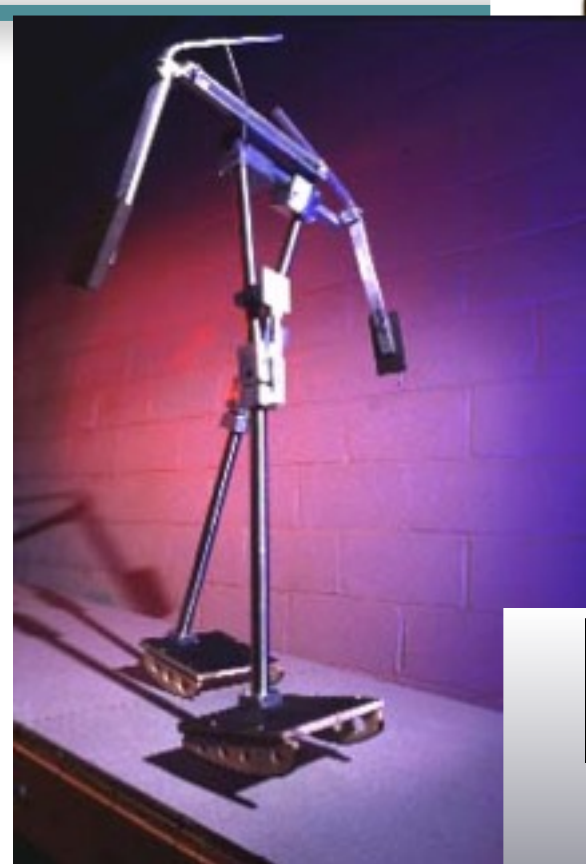
- emergence

"understanding by building"

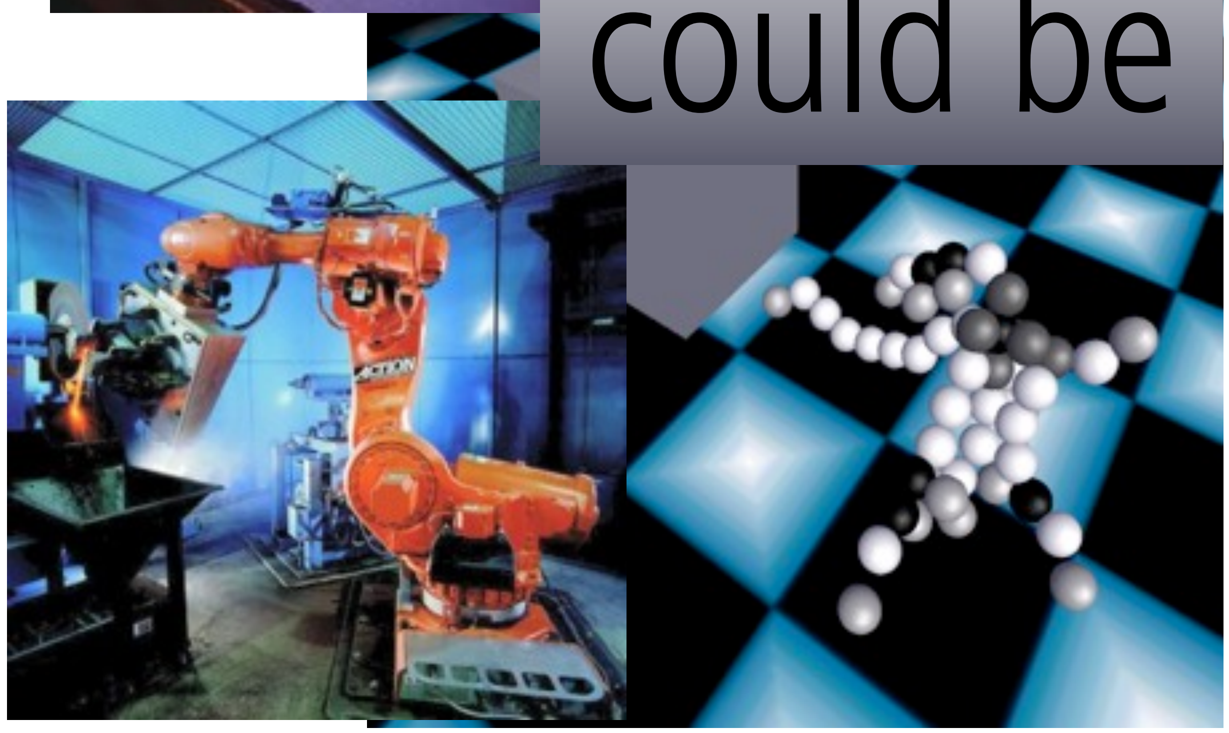
Intelligence/life
as it is — as it could be



Intelligence/life as it is — as it could be



life as it could be



life as it is

Steps toward a theory of intelligence

- level of generality and form of theory
- diversity-compliance
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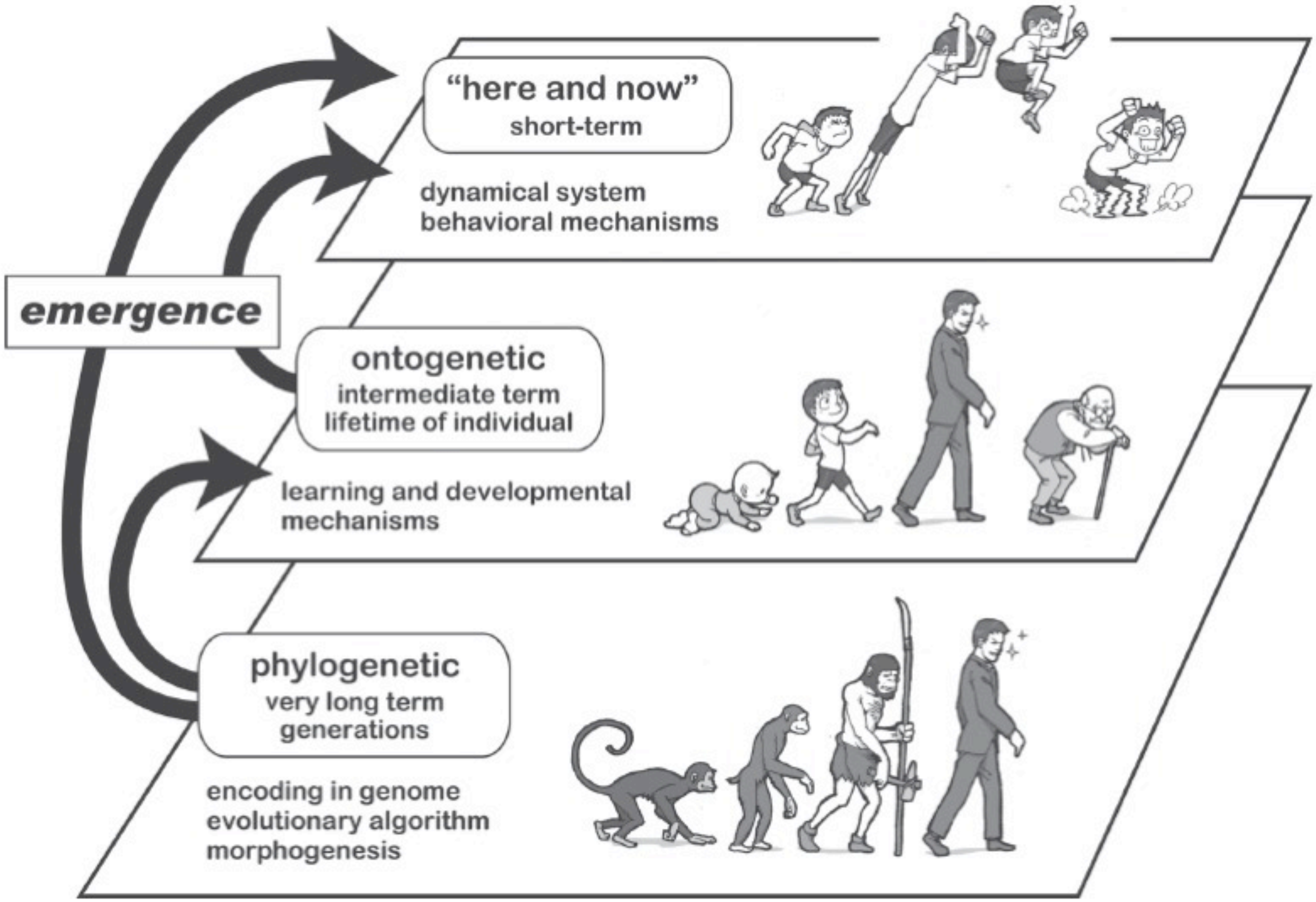
- **time perspectives**
- emergence

Time perspectives



Steps toward a theory of intelligence

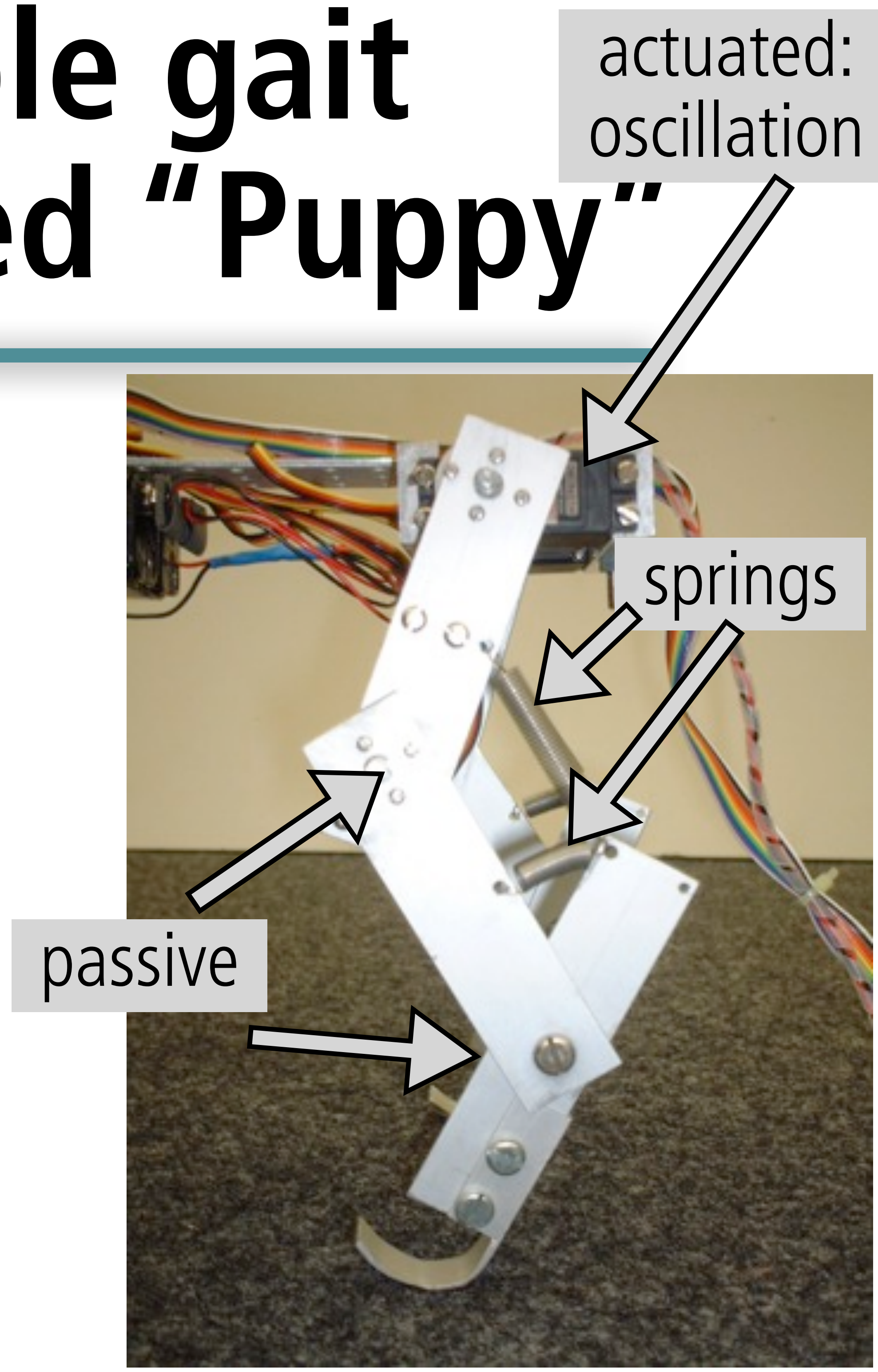
- level of generality and form of theory
- diversity-compliance
- frame-of-reference
- synthetic methdology
- time perspectives
- **emergence**

Emergence

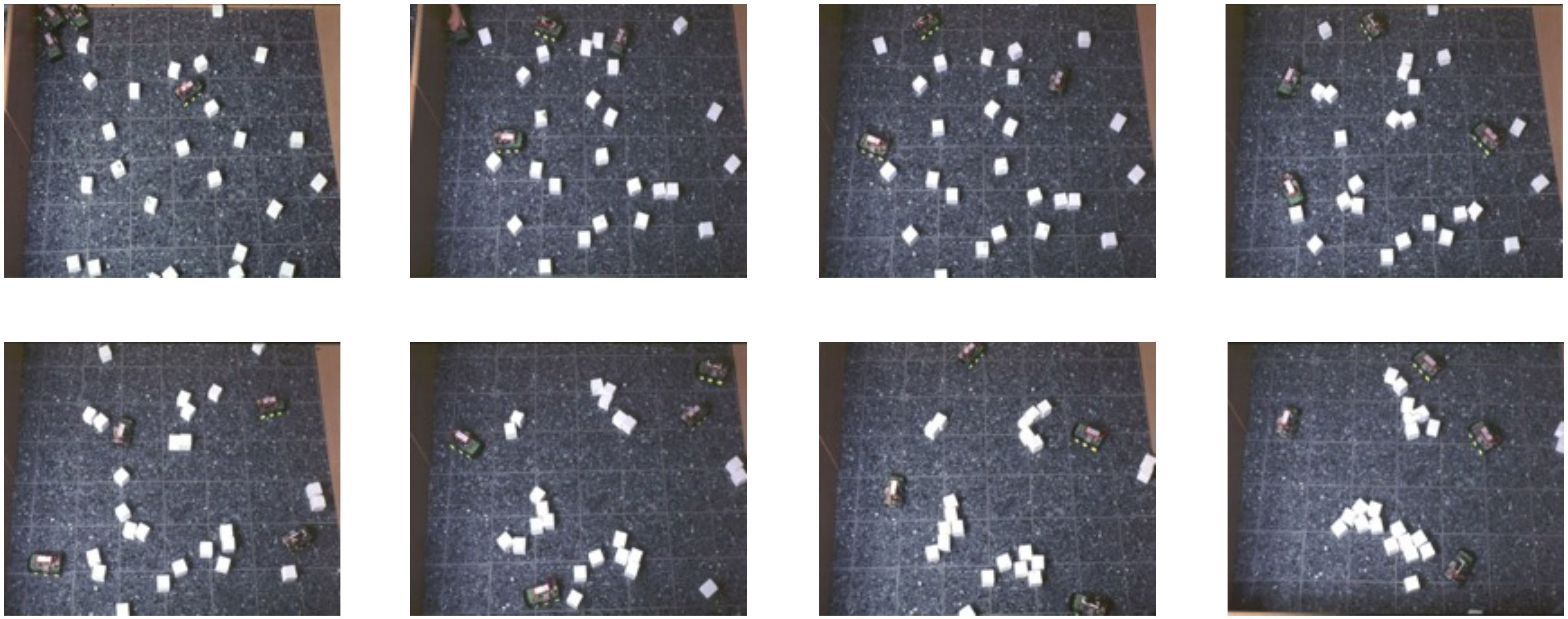
- behavior of individual
- global patterns from local interactions
- from time scales

Emergence of stable gait patterns: the quadruped "Puppy"

- simple control (oscillations of "hip" joints)
- spring-like material properties ("under-actuated" system)
- self-stabilization, no sensors
- "outsourcing" of functionality



Emergence of clustering



entire process: ∼20min
frames: 2-3min

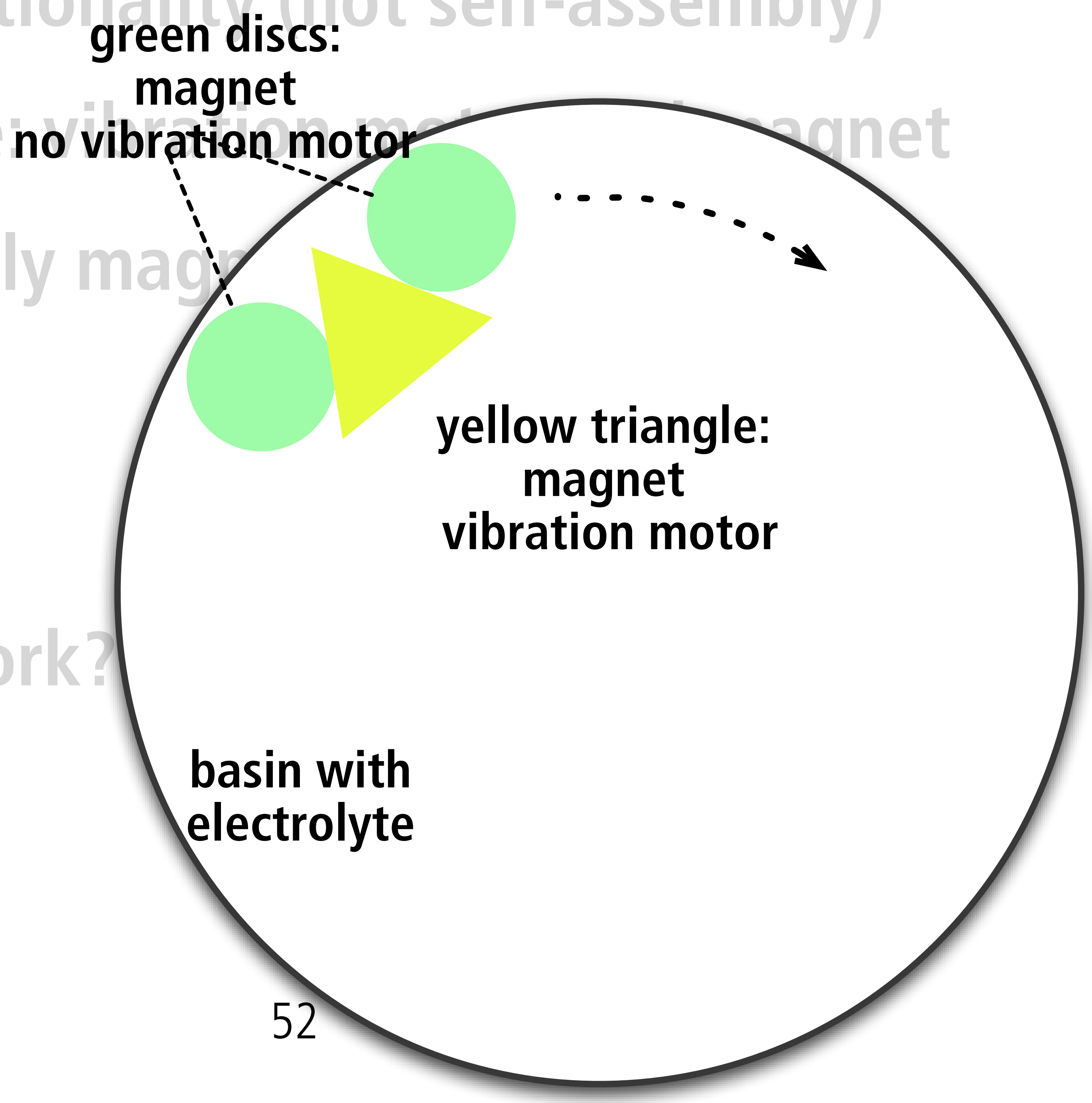
Design for emergence: a “bicycle” following the wall

emergent functionality (not self-assembly)

yellow triangle: ... agnet

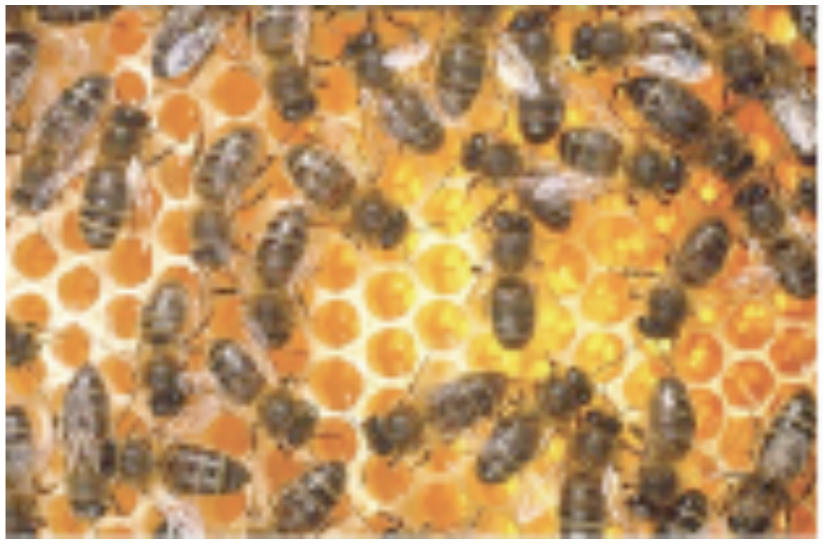
green discs: only mag

how does it work?



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 clearly demonstrates that we cannot only work in simulation (at least up to the point where this experiment was demonstrated, this could not have been achieved in simulation).

Emergence of global patterns from local rules — self-organization



bee hive

termite mound

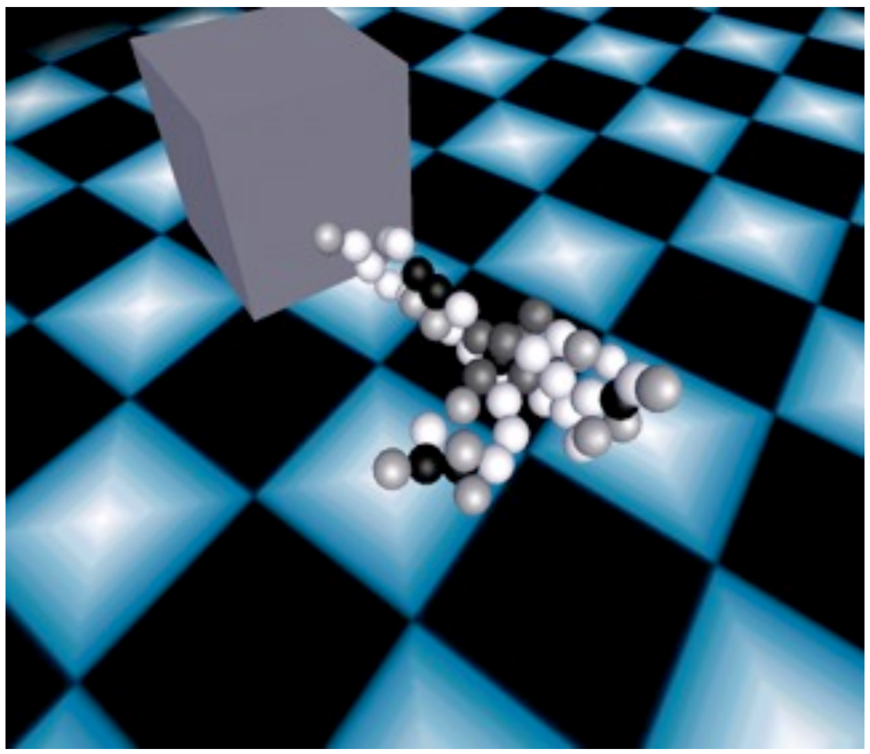
"wave" in stadium

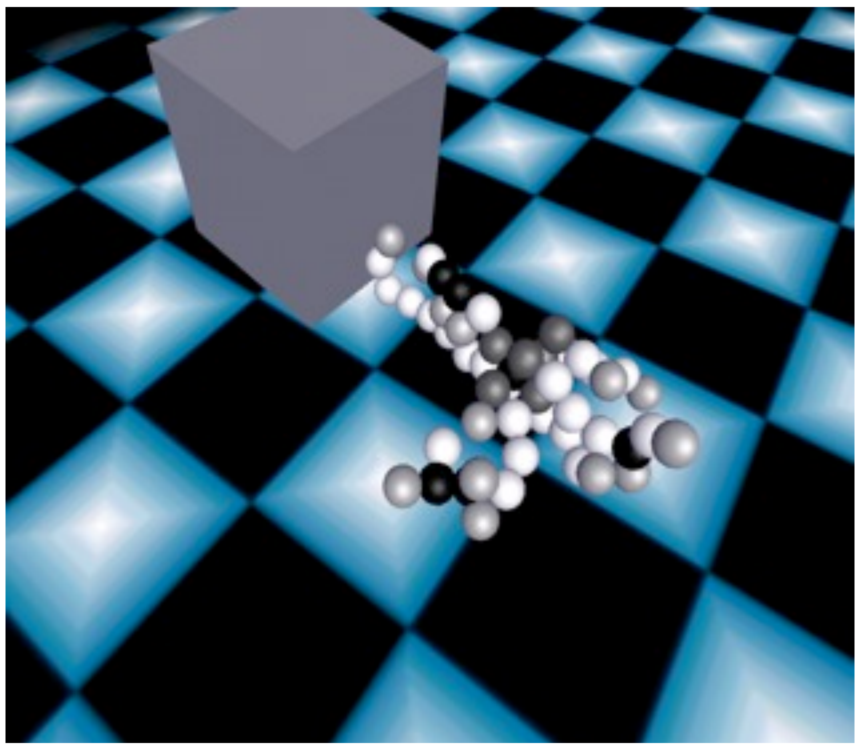
open source development community

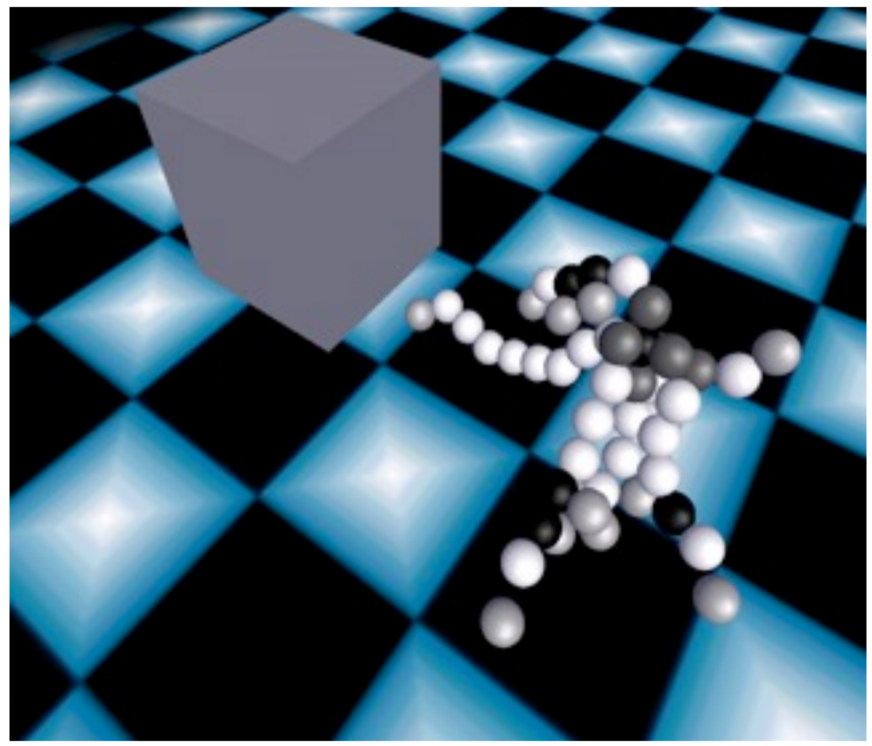
Emergence of behavior from time scales: locomotion and pushing

Bongard's "Block Pushers"

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







Emergence as a continuum

Steps toward a theory of intelligence

1. Meta-considerations: “Mind Set”
2. **Properties of physically embodied agents and of real world**
3. Design principles

Properties of physically embodied agents, e.g. “Puppy”

- subject to the laws of physics — gravity, friction
- generation of sensory stimulation through interaction with real world — angle, pressure sensors
- affect environment through behavior — exerting pressure on ground, crushing grass underfoot
- complex dynamical systems — gait patterns as attractor states
- perform morphological computation — materials (springs) take over part of control function

Characteristics of real-world environments

- information acquisition takes time
- information always limited
- noise and malfunction
- no clearly defined states
- multiple tasks
- rapid changes — time pressure
- non-linearity: intrinsic uncertainty

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Herbert Simon's concept of "bounded rationality"

Agent design principles

Agent design principles	**Description**
Three constituents	ecological niche, behaviors/tasks, and agents
Complete agent	complete agent, not only isolated components
Parallel, loosely coupled processes	parallel, asynchronous, processes, largely coupled through interaction with environment
Sensory-motor coordination	behavior sensory-motor coordinated with respect to target; self-generated sensory stimulation
Cheap design	exploitation of niche and interaction; parsimony
Redundancy	partial overlap in functionality based on different physical processes
Ecological balance	Balance in complexity of sensory-motor and neural system; task-distribution: morphology, materials, control, environment
Value	driving forces, developmental mechanisms, self-organization

Design principles for development

Principles for development	**Description**
Integration of time scales	many time scales need to be integrated into one agent
Development as an incremental process	start simply, build successively on top of what has already been learned
Discover	agent must have ability to explore and evaluate, which implies that agent can discover through its own activites
Social interaction	sensory-motor coordination together with social interaction provides most powerful engine for development
Motivated complexity	why complexity increases during ontogenetic development (driving force)

Design principles for evolution

Principles for evolution	Description
Population	Population is the prerequisite for evolution to function
Cumulative selection and self-organization	Cumulative selection will produce interesting results only if evolutionary process exploits processes of self-organization
Brain-body co-evolution	"Brain" (neural control) and body must be evolved simultaneously
Scalable complexity	In order for complex organisms to emerge, the ontogenetic developmental processes must be encoded in the genome
Evolution as a fluid process	Agents should be modeled with a large number of cells: evolution should make only small modifications (at the genome)
Minimal designer bias	Design as little as possible and let evolution do as much work as possible

Design principles for collective intelligence

Principles for collective systems	**Description**
Level of abstraction	Proper level of abstraction must be chosen, and the implications (of abstraction) important
Design for emergence	Find local rules of interaction that lead to desired global behavioral patterns (holds also for individual agents)
From agent to group	Agent design principles often applicable to collective systems (e.g. parallel, loosley coupled processes)
Homogeneity-heterogeneity tradeoff	Find compromise between systems using only one type of module/robot and systems emplying several specialized types

Illustrations of design principles
Selected highlights

(see additional slides - study materials)

Agent design principles

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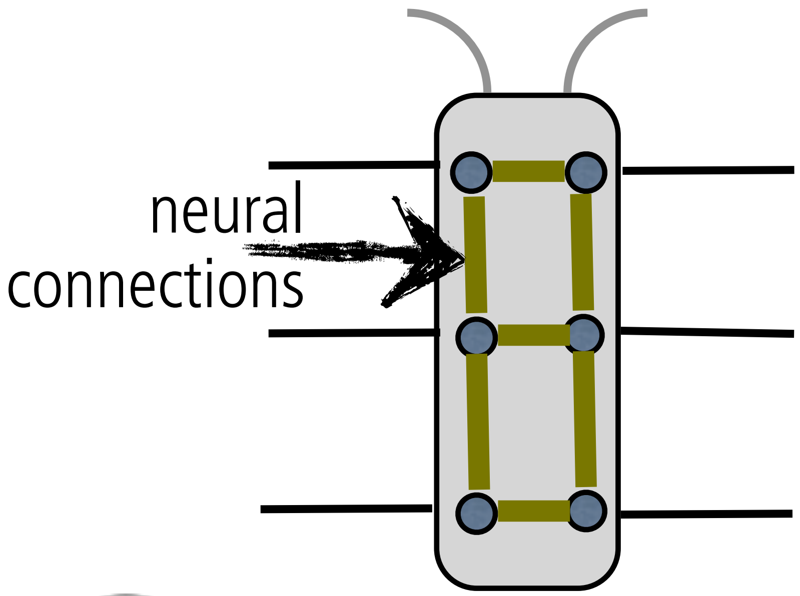
Parallel, loosely coupled processes

Holk Cruse, German biologist



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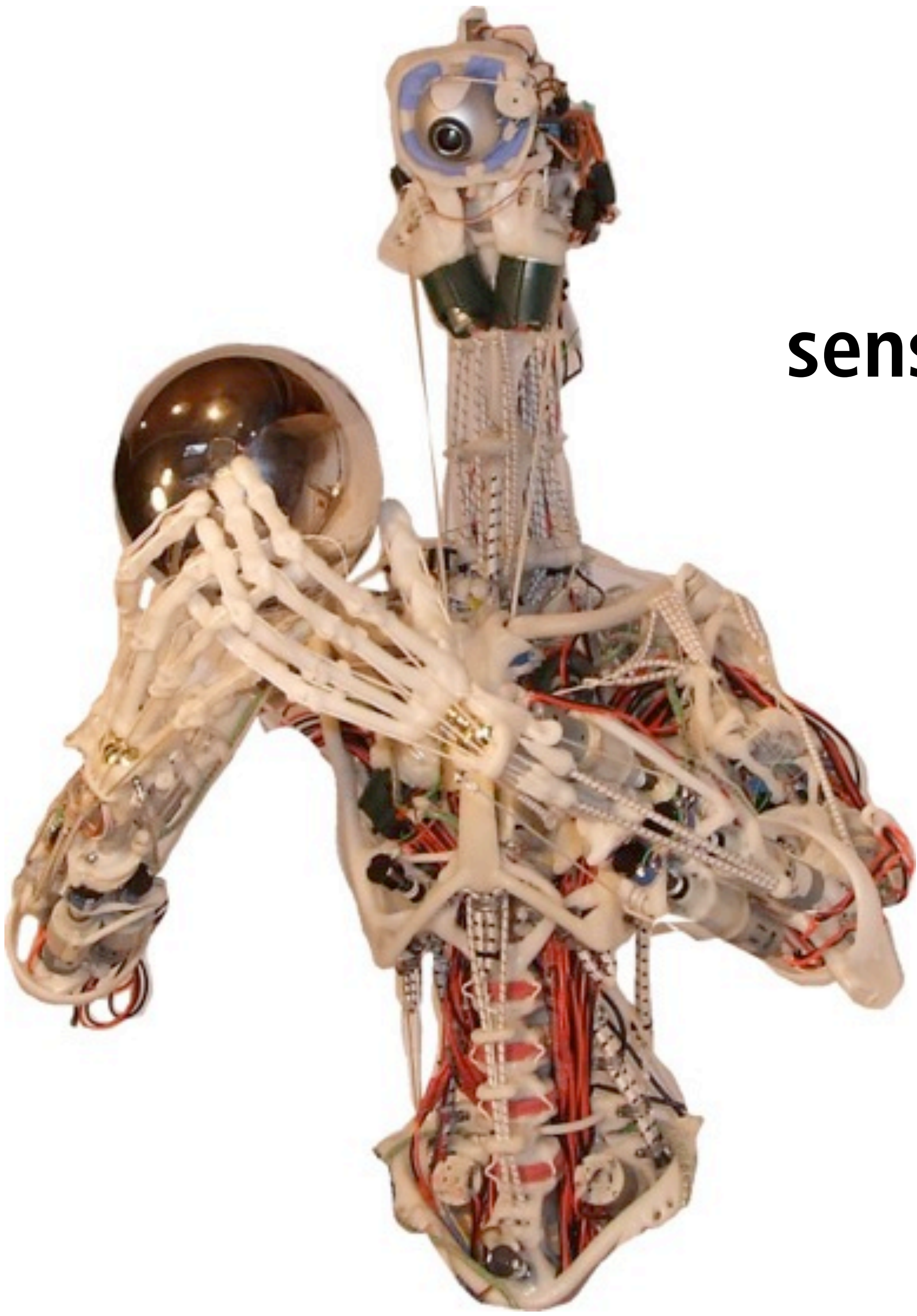
Parallel, loosely coupled processes

coupling through pheromone trails in environment

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!!!

Sensory-motor coordination
Information self-structuring



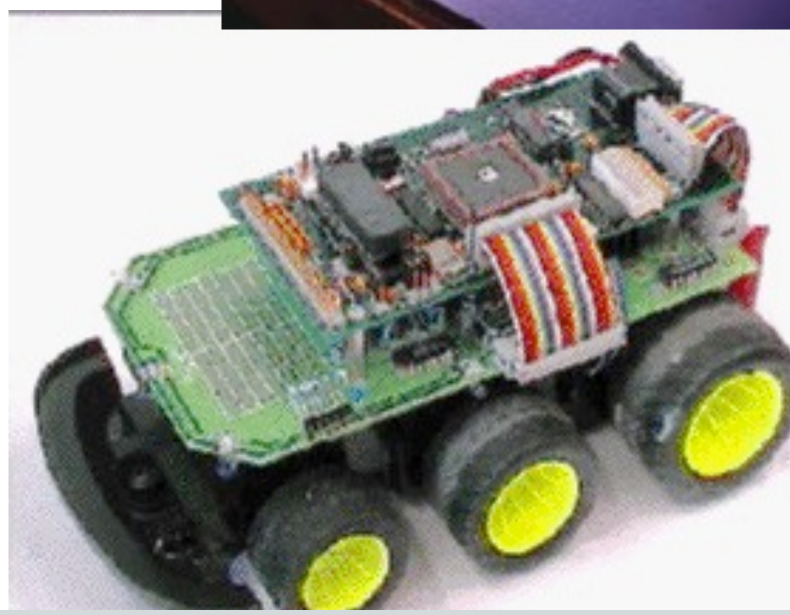
induction of patterns of sensory stimulation containing information structure through sensory-motor coordinated interaction (e.g. grasping, foveating)

As pointed out many times, through sensory–motor coordinated interaction with the environment, information structure is induced.

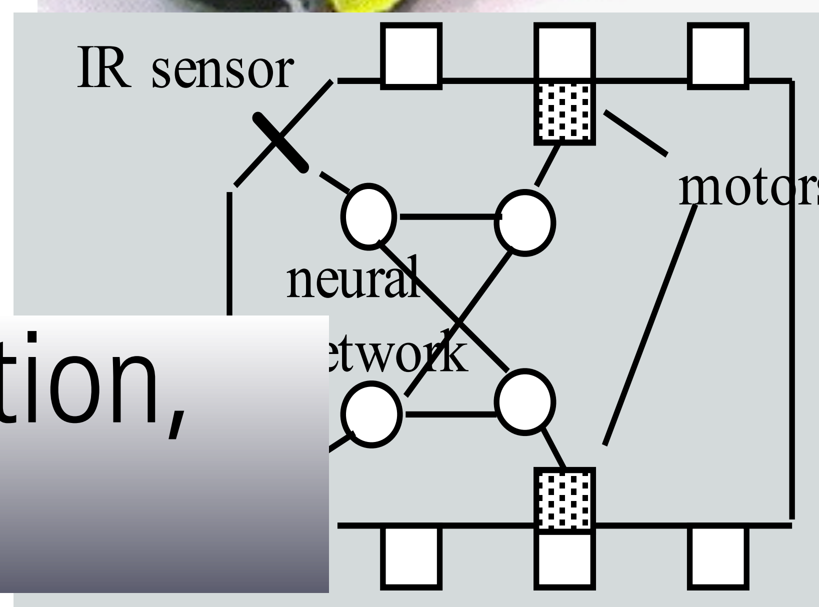
Cheap design exploitation of niche

Passive Dynamic
Walker

6x6m arena with Styrofoam cubes



Didabot
simple robot
for didactial
purposes



exploiting: borders, shape, weight, friction, morphology, weight distribution

Daniel Dennett: “These robots are cleaning up, but that’s not what they think they are doing“ (joke — can the think?)

Cheap design
simple mechanism

behavioral rule:

sensory stimulation on left: turn right

sensory stimulation on right: turn left

(obstacle avoidance)

→

exploiting: borders, shape, weight, friction, morphology

Redundancy
Different physical processes

airplane landing

jet engines
(reverse) propulsion

braking systems
partial overlap of functionality

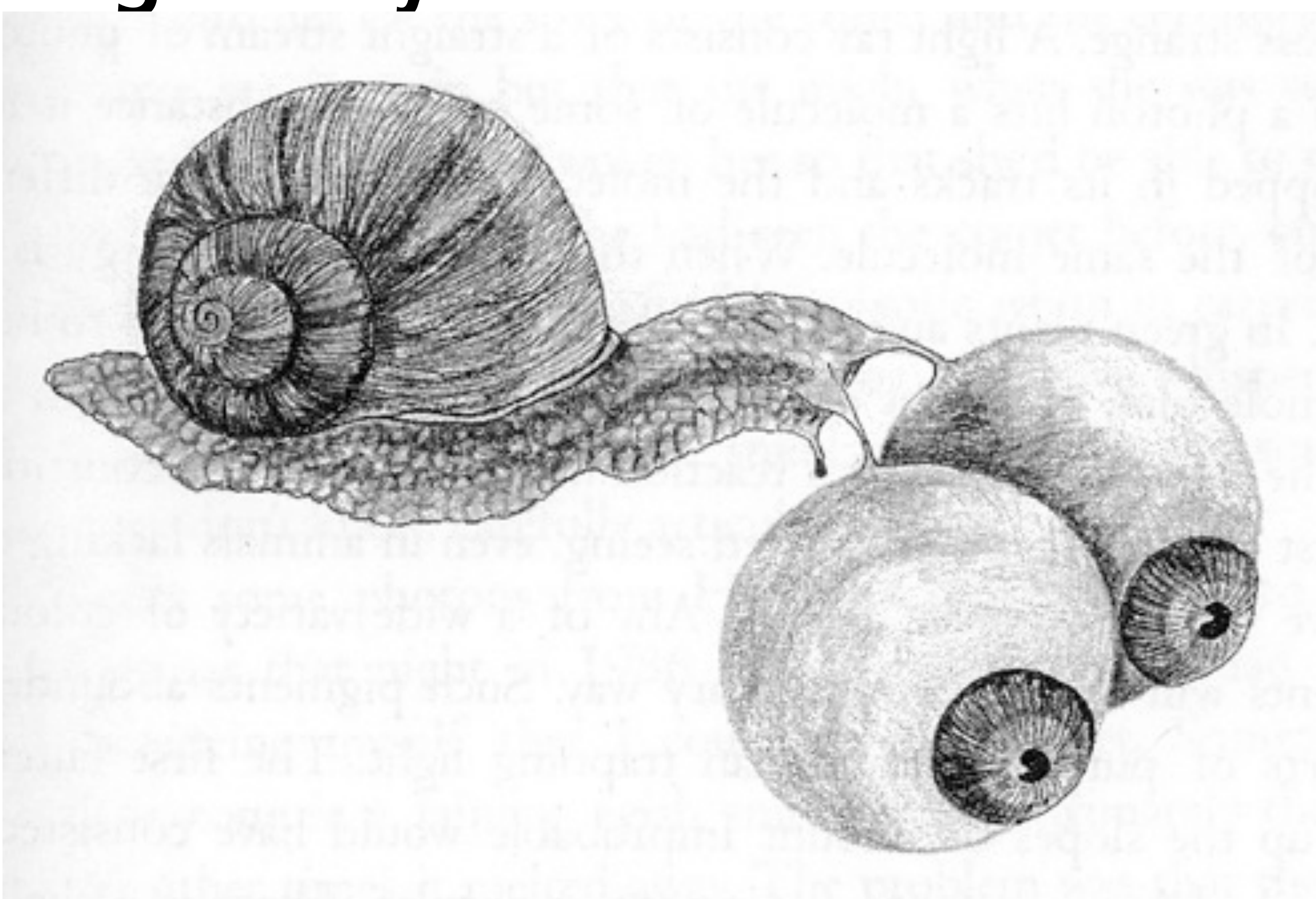
parachutes
mechanical

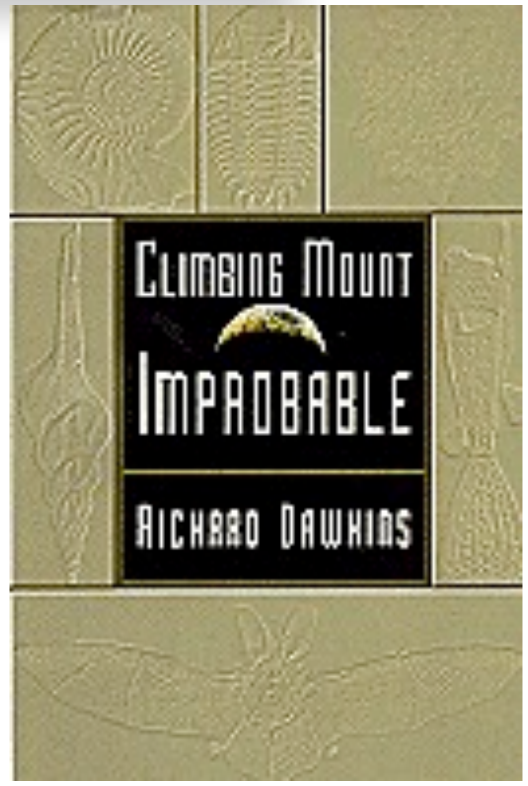
wheels (friction)
runway conditions

There is a partial overlap of functionality in the different sensory patterns.

Ecological balance matching complexity

ecologically unbalanced system: Richard Dawnkins's snail with giant eyes

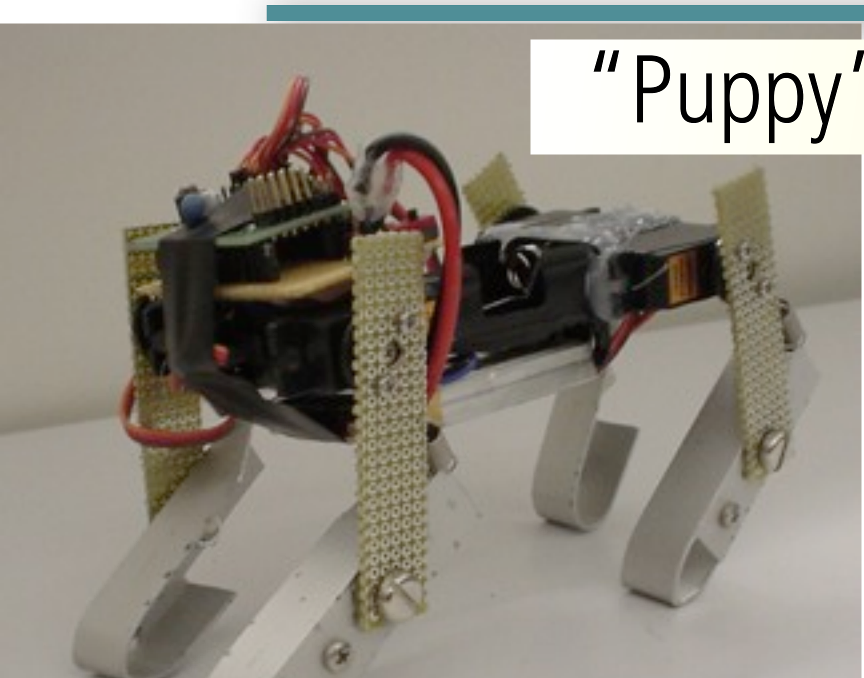




Author of:
"The selfish gene" and
"The blind watchmaker"

What are such huge eyes good for if the snail cannot move quickly? It's only useless additional weight.

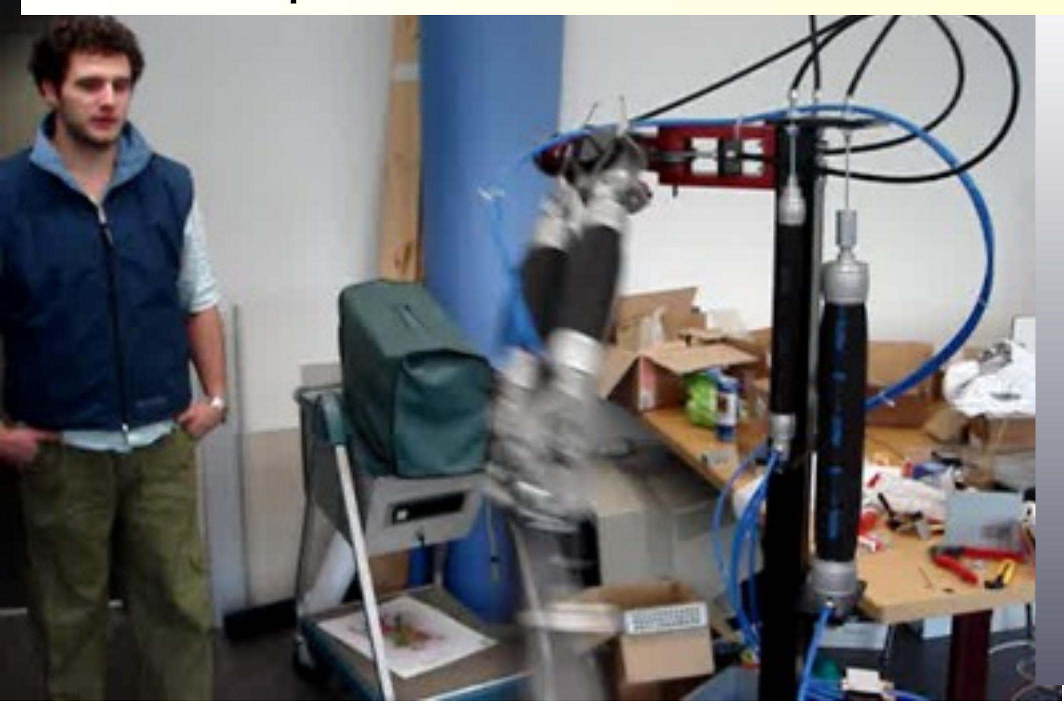
Ecological balance: task distribution morphology, materials, control



"Puppy" with springs

Robot "frog" Mowgli
U-Tokyo
with pneumatic actuators

loosely swinging arm
with pneumatic actuators



control partially "outsourced" to properties of springs, pneumatic actuators

Design principles for development

Principles for development	**Description**
Integration of time scales	many time scales need to be integrated into one agent
Development as an incremental process	start simply, build successively on top of what has already been learned
Discover	agent must have ability to explore and evaluate, which implies that agent can discover through its own activites
Social interaction	sensory-motor coordination together with social interaction provides most powerful engine for development
Motivated complexity	why complexity increases during ontogenetic development (driving force)

Bernstein's problem:
Development as an incremental process

learning to control high DOF body: freezing and freeing DOFs

Not all degrees of freedom are used at the outset, but some are "frozen" and only freed up once a basic set of movements is in place.

Discover, learn from real world
The best exploration strategies

only possible through embodiment

exploration: **NOT random! —> preferred trajectories from biomechanical constriaints**

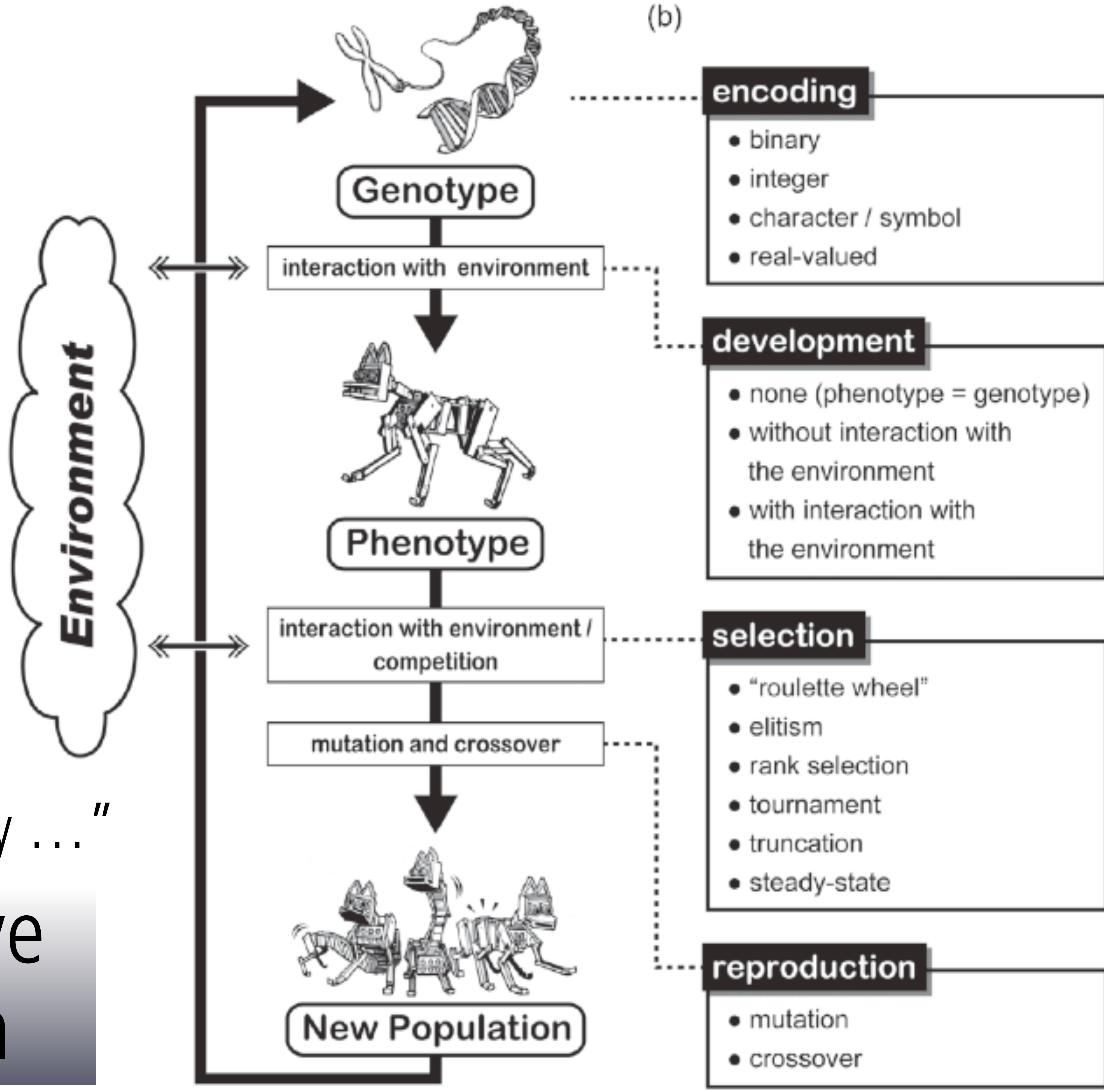
"loosely swinging arm"

Biomechanical constraints solve one of the fundamental problems in learning, the reduction of the huge search spaces. Following the preferred trajectories increases the probability of an "interesting" interaction with the real world (i.e. where something can be learned).

Design principles for evolution

Principles for evolution	**Description**
Population	Population is the prerequisite for evolution to function
Cumulative selection and self-organization	Cumulative selection will produce interesting results only if evolutionary process exploits processes of self-organization
Brain-body co-evolution	“Brain” (neural control) and body must be evolved simultaneously
Scalable complexity	In order for complex organisms to emerge, the ontogenetic developmental processes must be encoded in the genome
Evolution as a fluid process	Agents should be modeled with a large number of cells: evolution should make only small modifications (at the genome)
Minimal designer bias	Design as little as possible and let evolution do as much work as possible

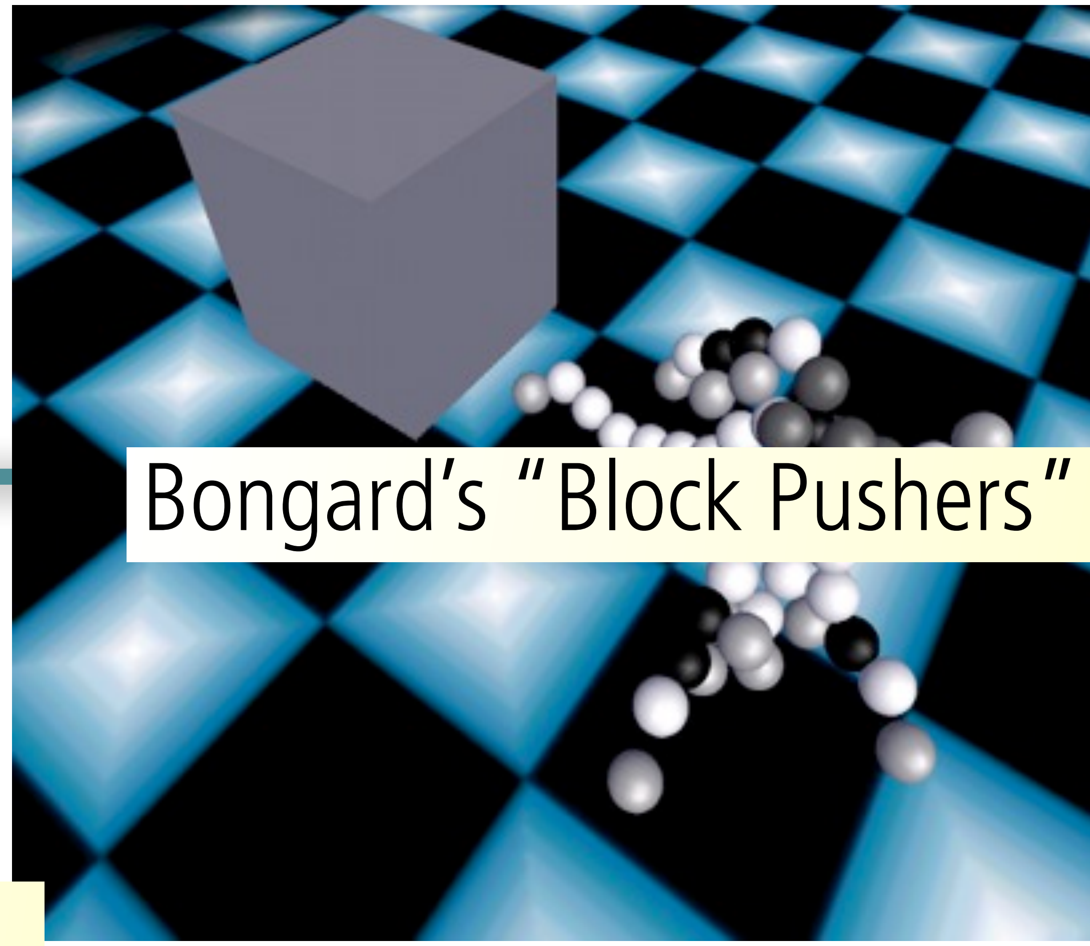
Basic cycle for artificial evolution



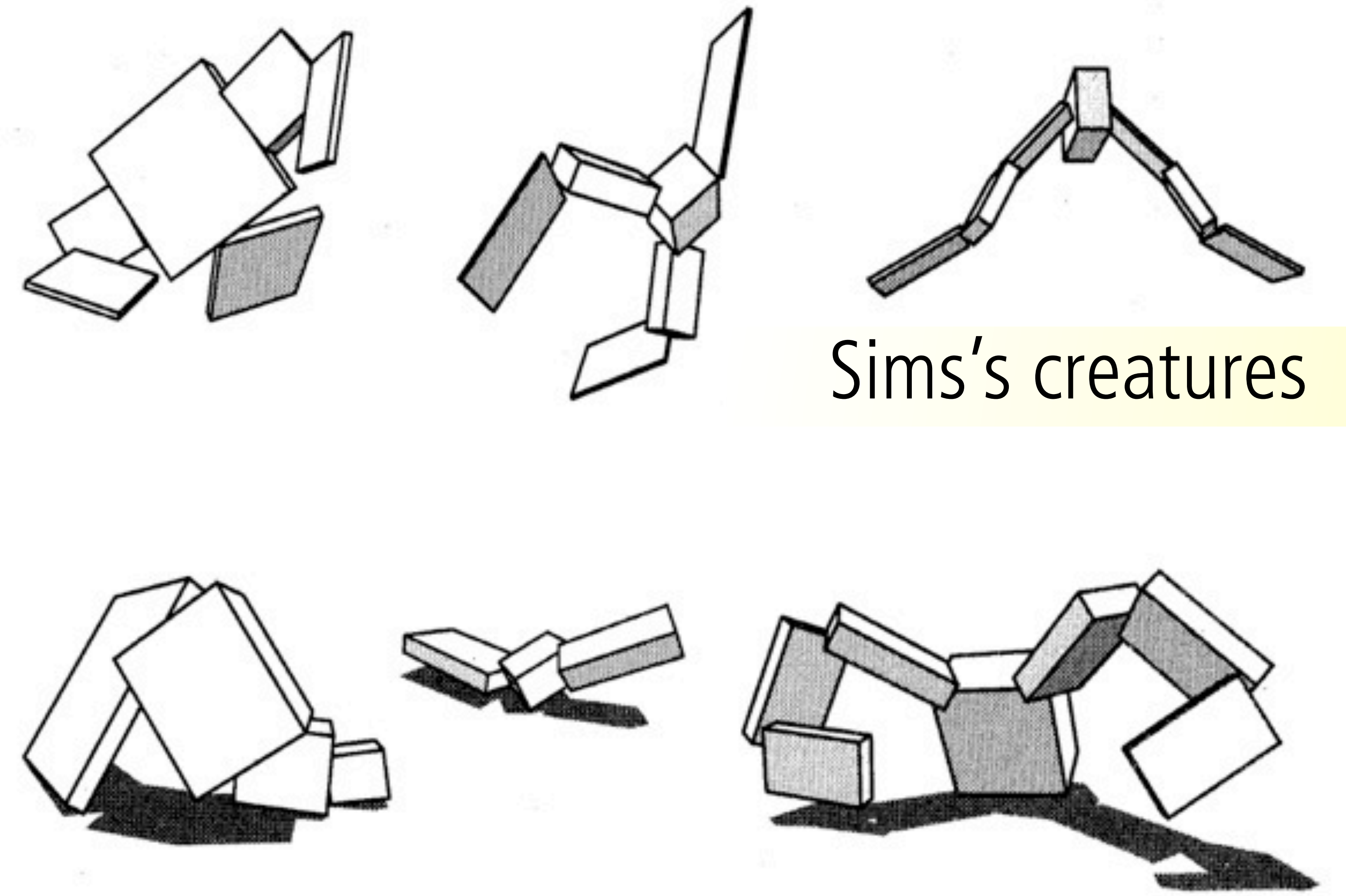
from
"How the body …"

cumulative selection

Brain-body co-evolution



Bongard's "Block Pushers"



Sims's creatures

Lipson's creatures
"Golem" project

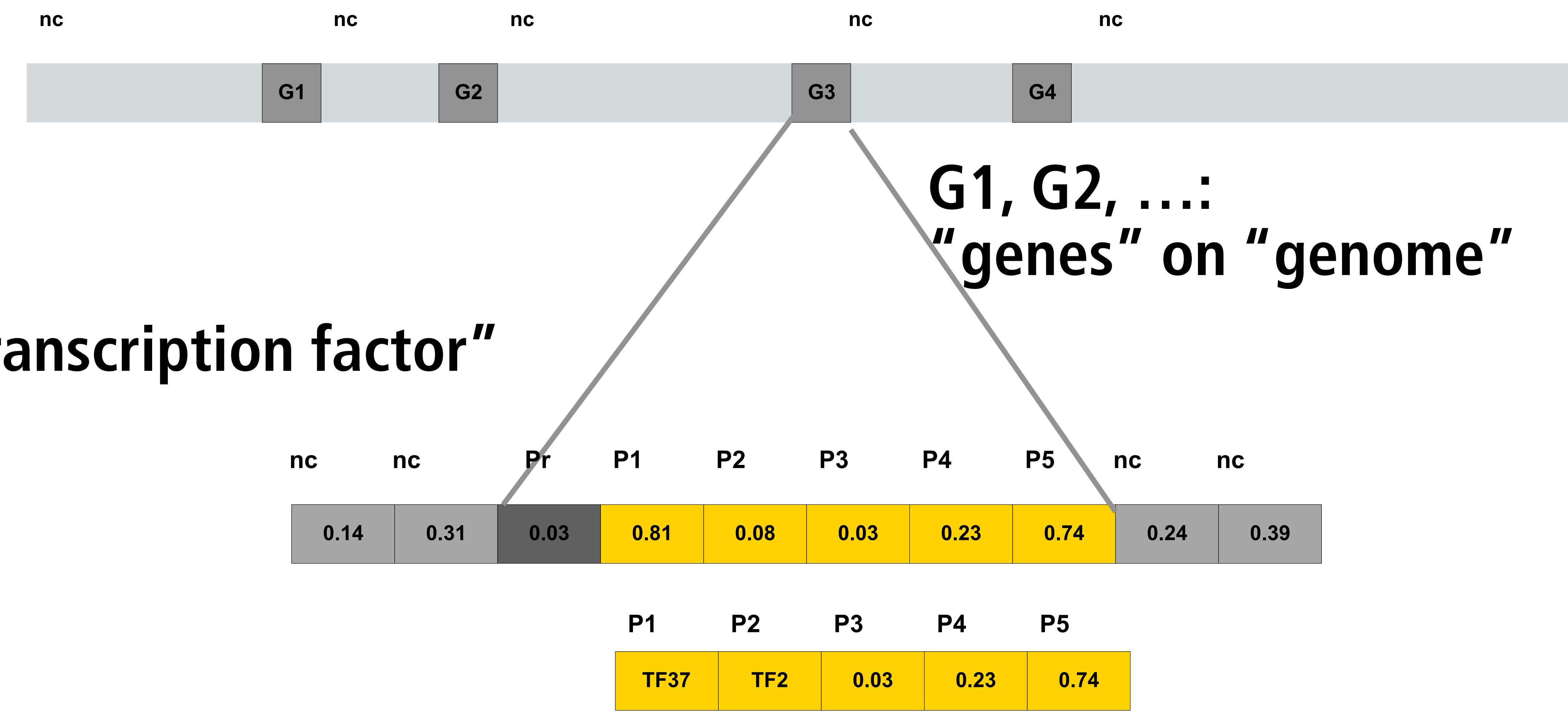
Sims and Golem: parameterization of body structure
Bongard: GRNs (Genetic Regulatory Networks)

Encoding of developmental processes in genome

rather than the structure of the organism

Encoding developmental processes Representation of “gene”

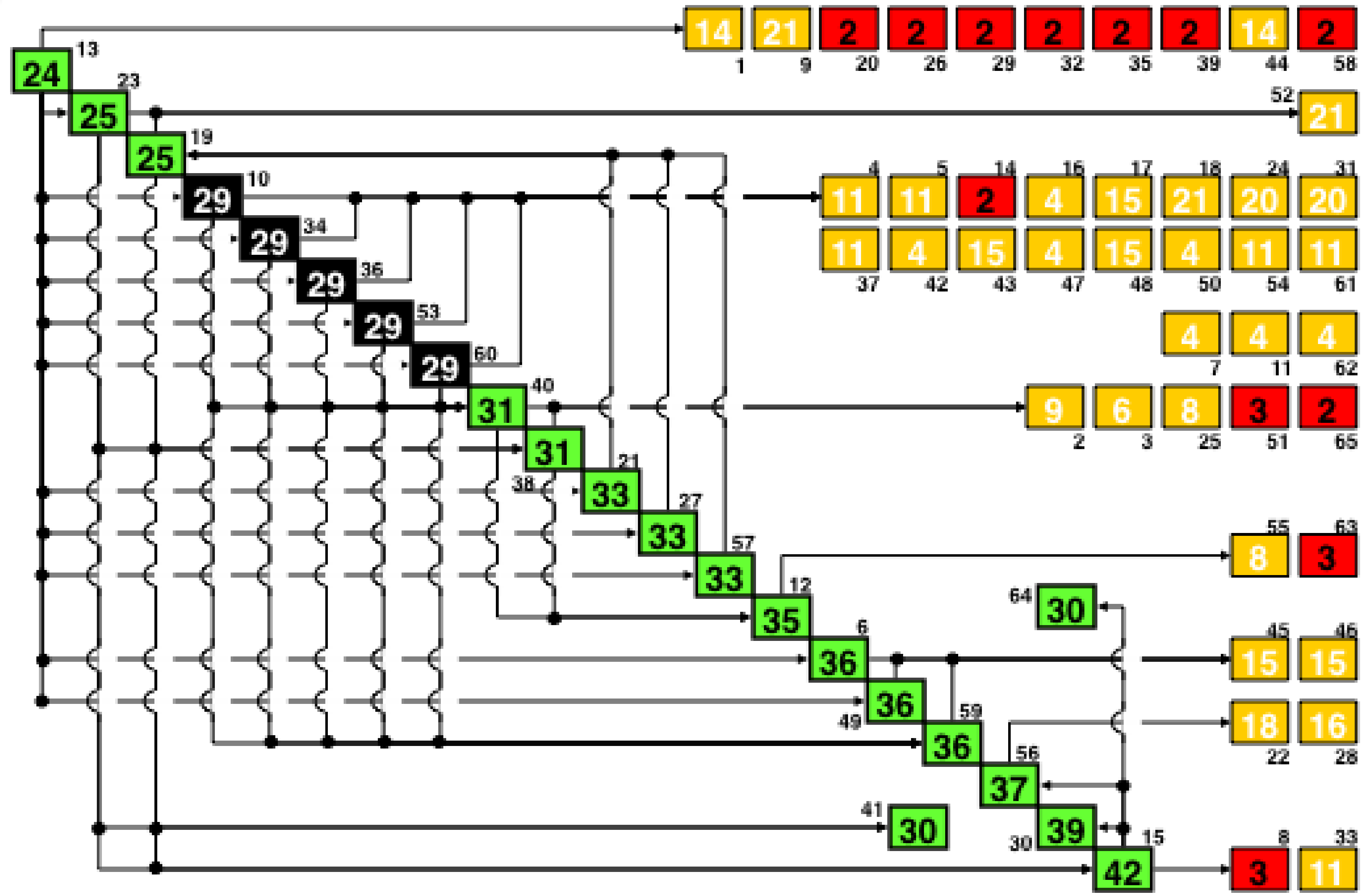
nc: “non-coding region”



G1, G2, …: “genes” on “genome”

TF: “transcription factor”

GRN for evolved creature (Josh Bongard)



Design principles for collective intelligence

Principles for collective systems	**Description**
Level of abstraction	Proper level of abstraction must be chosen, and the implications (of abstraction) important
Design for emergence	Find local rules of interaction that lead to desired global behavioral patterns (holds also for individual agents)
From agent to group	Agent design principles often applicable to collective systems (e.g. parallel, loosley coupled processes)
Homogeneity-heterogeneity tradeoff	Find compromise between systems using only one type of module/robot and systems emplying several specialized types

End of additional materials for self-study