
人工智能
上海
The
ShanghAI
Lectures
授课

The ShanghAI Lectures

An experiment in global teaching

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The BioRobotics Institute, SSSA and Heron Robots

Today from the BioRobotics Institute, Pontedera (PI)

欢迎您参与
“来自上海的人工智能系列讲座”

Lecture 5

Evolution: Cognition from Scratch, Cognition from Interaction

24 November 2016

skype: PhD.Biorobotics

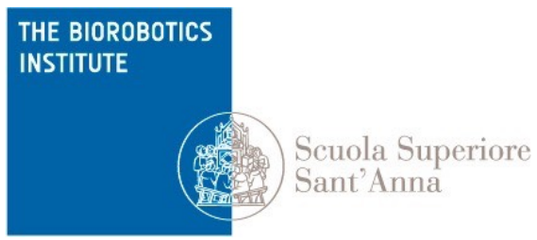
(only for lecture sites connected by streaming

ISTITUTO DI BIOROBOTICA
Scuola Superiore Sant'Anna

The ShanghAI Lectures 人工智能 上海授课

The need for an embodied perspective

- “failures” of classical AI
- fundamental problems of classical approach
- Wolpert’s quote: Why do plants not have a brain? (but check Barbara Mazzolai’s lecture at the ShanghAI Lectures 2014)
- Interaction with environment: always mediated by body



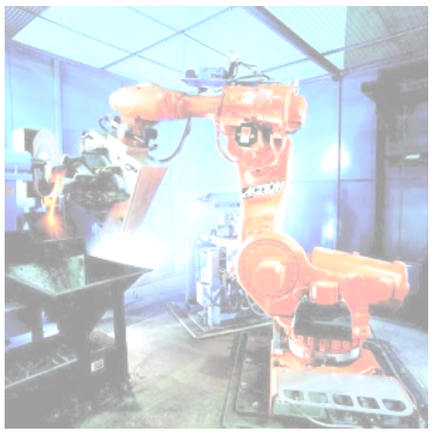
“English Room” thought experiment

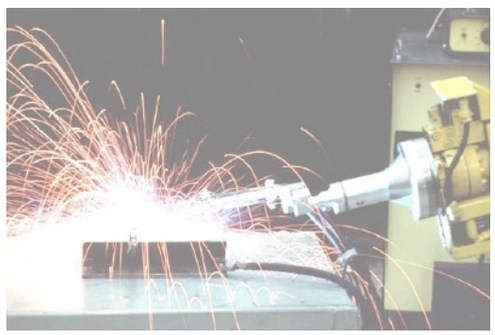
- “this is Spanish for me” (in Austria to say a speech is impossible to understand) - (funny for me, for an Italian Spanish is quite easy :-))

Successes and failures of the classical approach

successes	failures
applications (e.g. Google)	**foundations of behavior**
chess	**natural forms of intelligence**
manufacturing	**interaction with real world**
(“controlled”artificial worlds)	

Industrial robots vs. natural systems





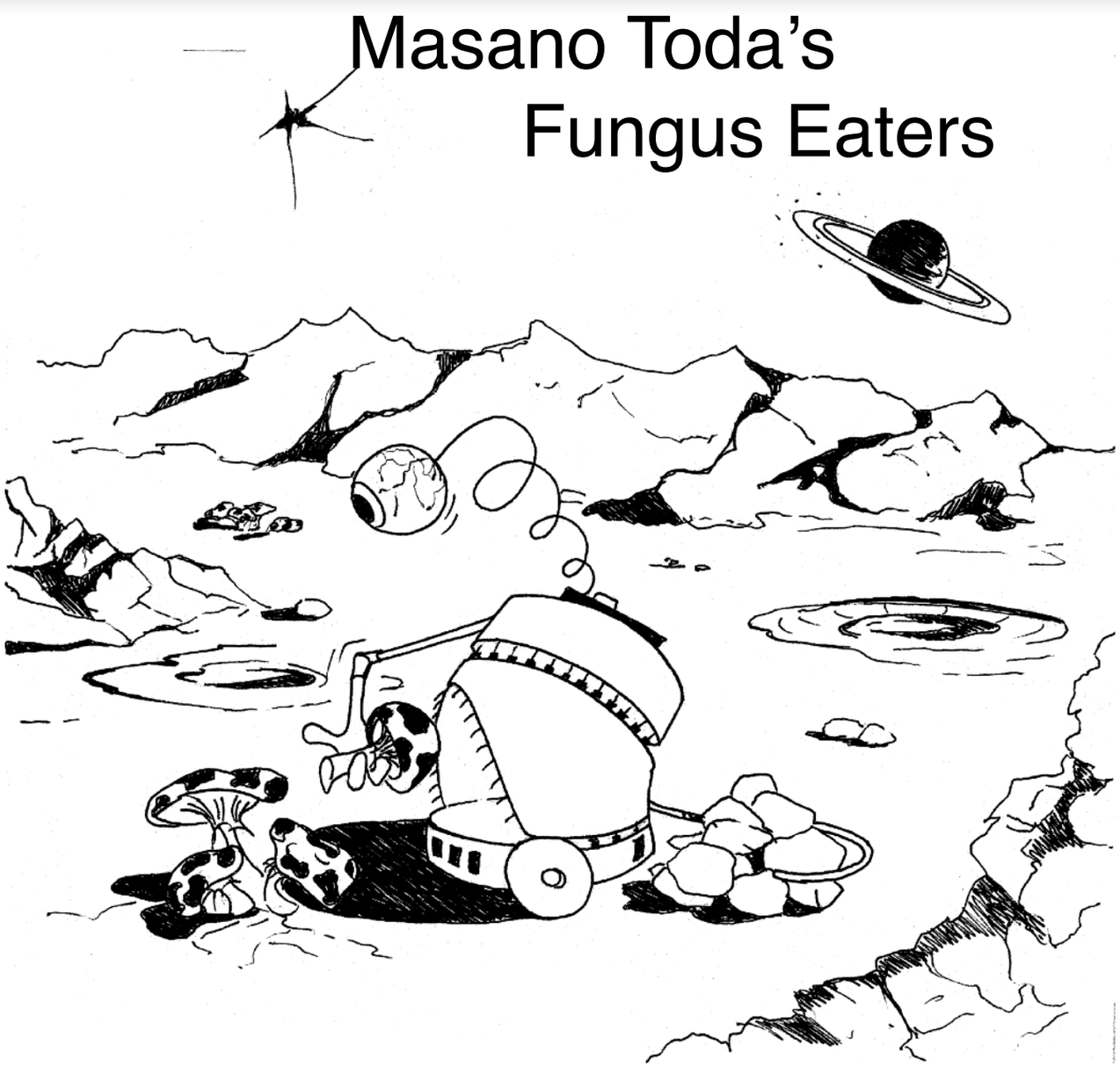
robots

principles:
- **low precision**
- **compliant**
- **reactive**
- **coping with uncertainty**

humans

→ **no direct transfer of methods**

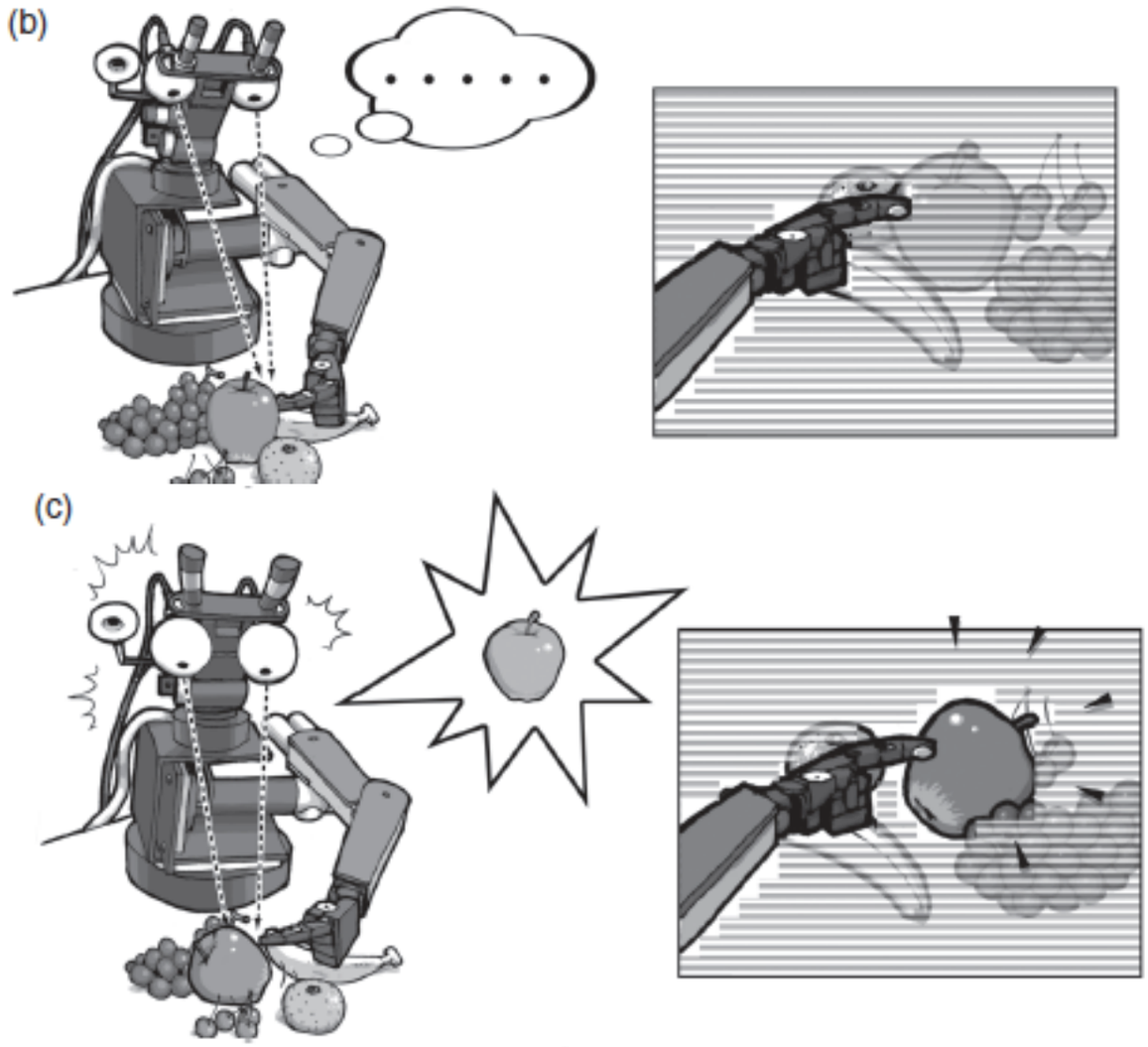
Complete agents



Properties of embodied agents

- subject to the laws of physics
- generation of sensory stimulation through interaction with real world
- affect environment through behavior
- complex dynamical systems
- perform morphological computation

Recognizing an object in a cluttered environment



manipulation of environment can facilitate perception

Experiments: **Giorgio Metta and Paul Fitzpatrick**

Illustrations by Shun Iwasawa

Today's topics

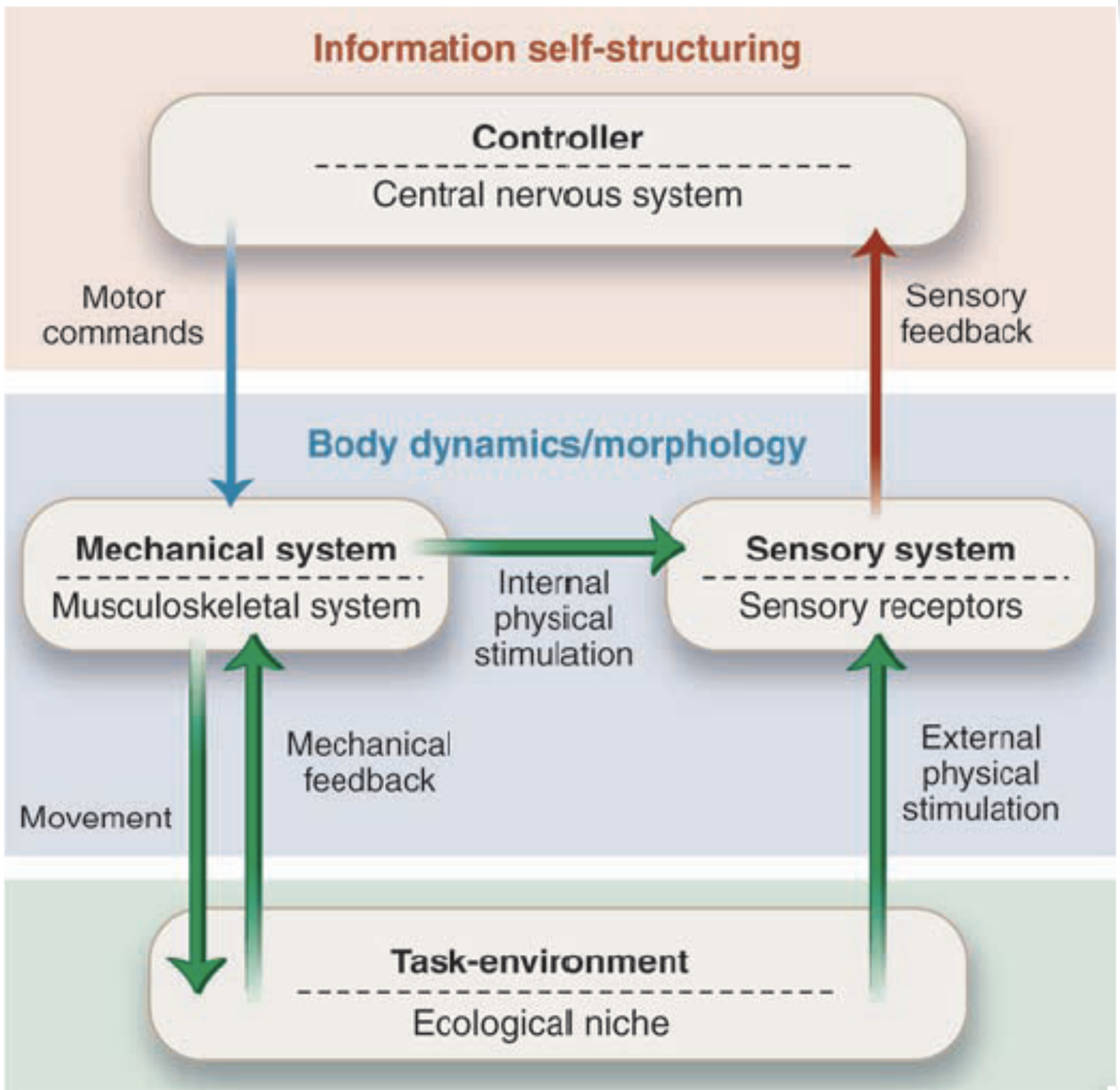
- short recap
- characteristics of complete agents
- illustration of design principles
- **parallel, loosely coupled processes: the "subsumption architecture"**
- case studies: "Puppy", biped walking
- "cheap design" and redundancy

Parallel, loosely coupled processes

intelligent behavior:

- **emergent from system-environment interaction**
- **based on large number of parallel, loosely coupled processes**
- **asynchronous**
- **coupled through agent's sensory-motor system and environment**

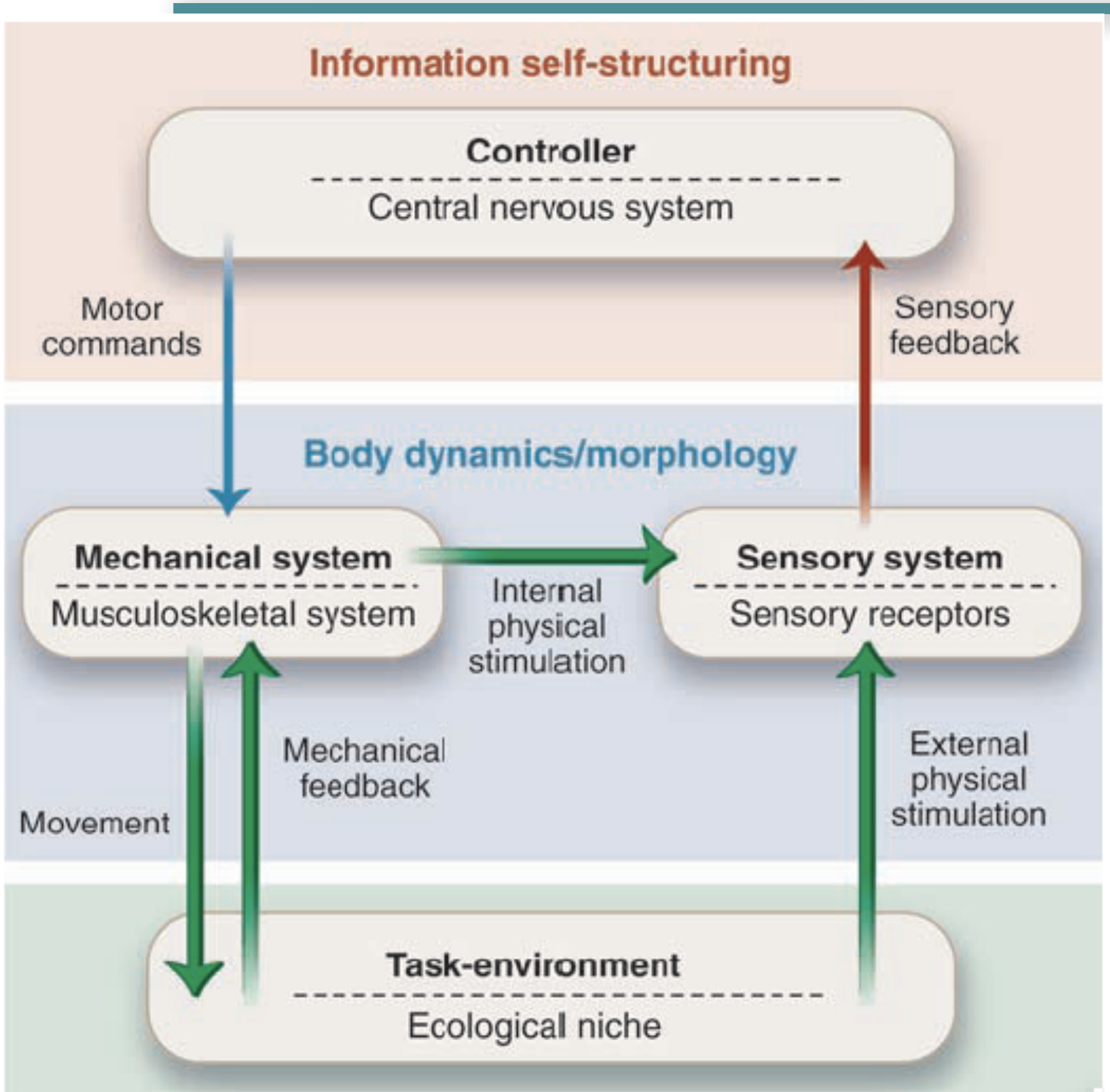
Implications of embodiment



"Puppy"

Pfeifer et al.,Science, 16 Nov. 2007

Implications of embodiment



"Puppy"

which part of diagram is relevant?

—>

Pfeifer et al.,Science, 16 Nov. 2007

How to quantify?

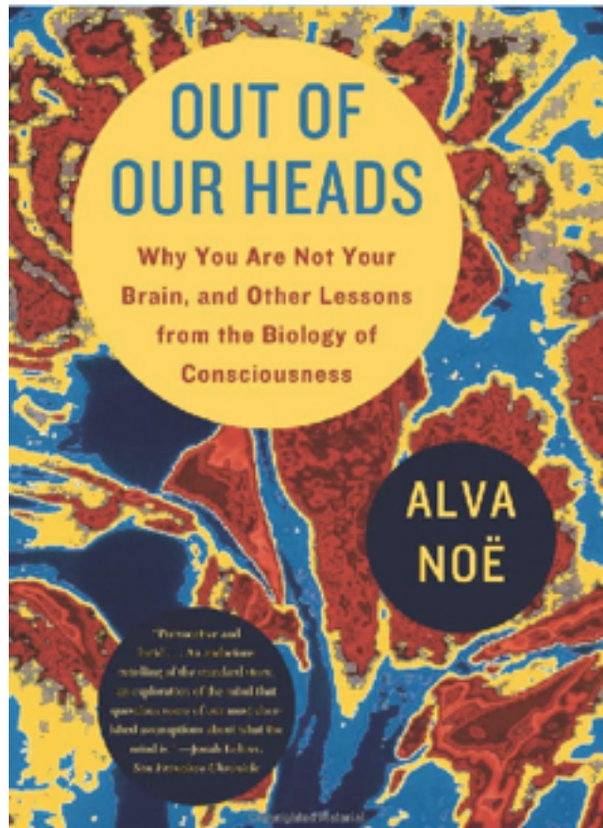
- **Some hints in Lecture 7!**

“The brain in the vat”

“Brain-in-a-vat”

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

- **supply energy**
- **flush away waste products**
- **complicated: providing stimulation comparable to that normally provided to a brain by its environmentally situated body**



“Brain-in-a-vat”

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

volunteer for short presentation of “Brain-in-a-vat” (1 December 2016)

- supply en
- flush awa
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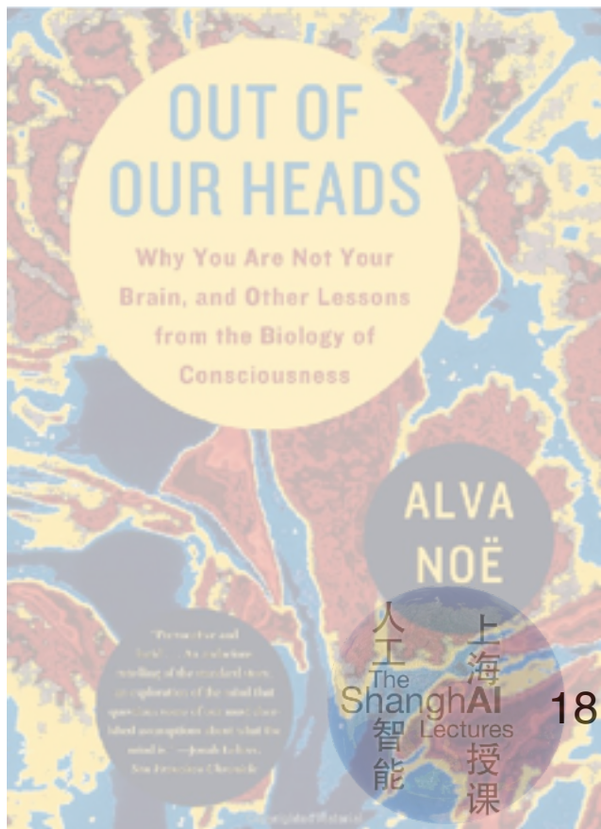
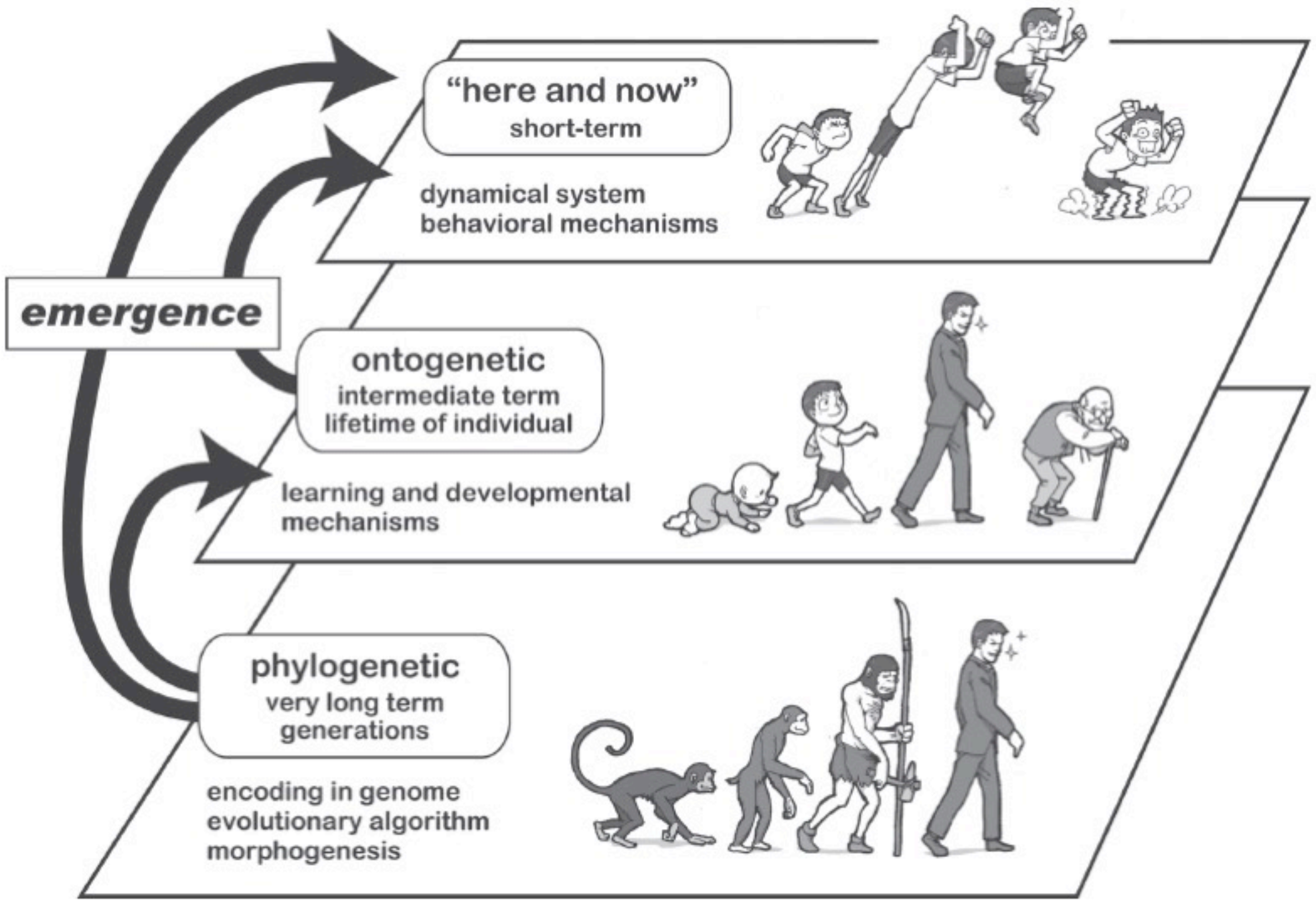


Artificial Neural Networks

many excellent books available

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

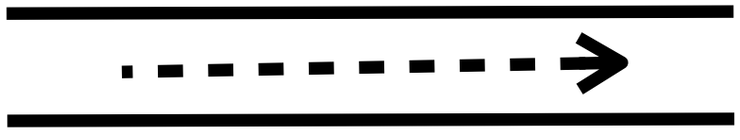
“ontogenetic” perspective

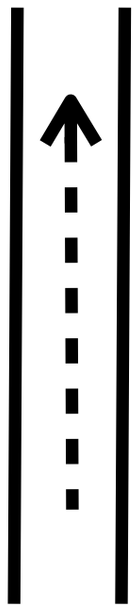
evolutionary
evolutionary

“phylogenetic” perspective

Understanding: **all three perspectives requires**
Design: **level of designer commitments, relation to autonom**

Rechenberg's "fuel pipe problem"





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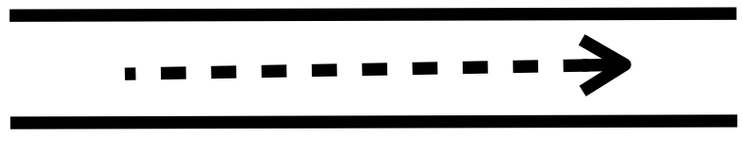
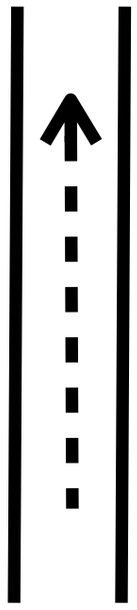
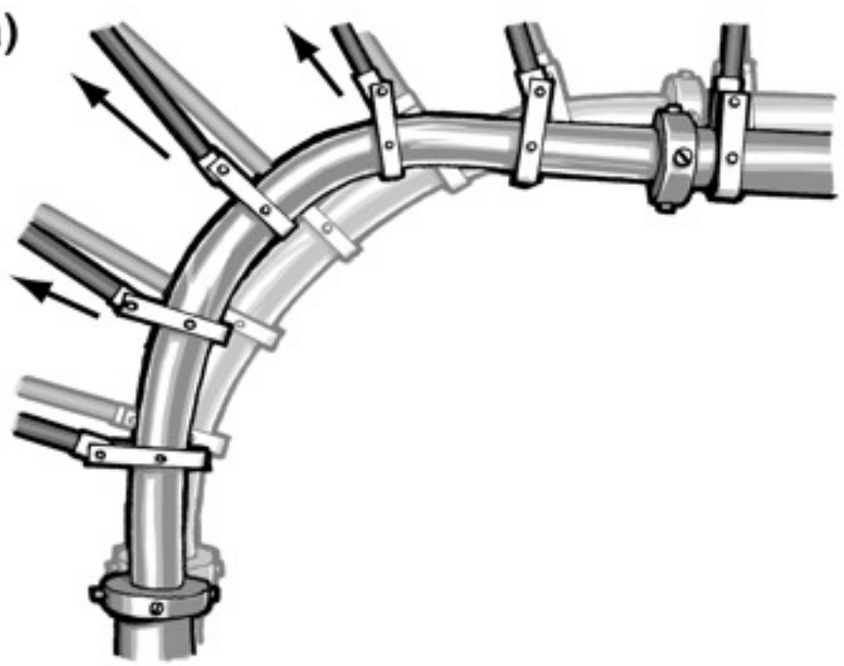


Creative?

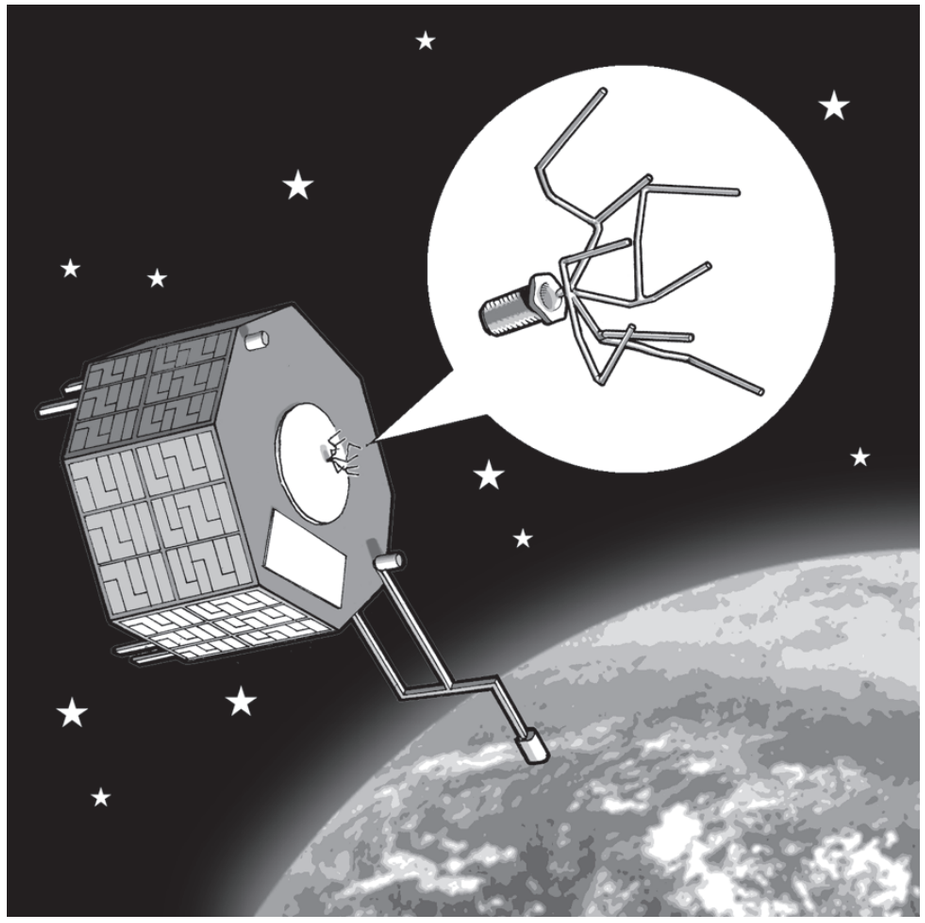


Evolutionary designs

(a)



(b)



evolutionary designs: (a) Rechenberg's "fuel pipe", (b) antenna for satellite

Evolutionary designs

GECCO
(Genetic and Evolutionary Computation Conference)

Human-competitive design

evolutionary designs: (a) Rechenberg's "fuel pipe", (b) antenna for satellite

Artificial evolution

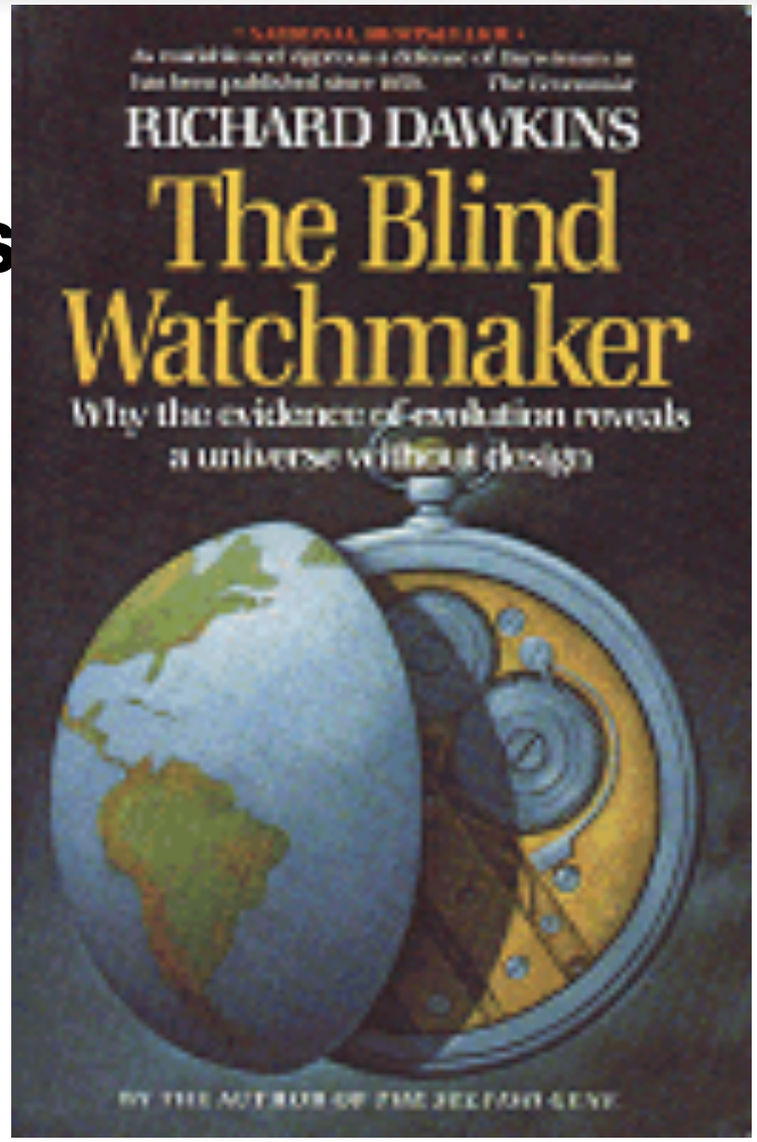
- John Holland
- Ingo Rechenberg
- John Koza

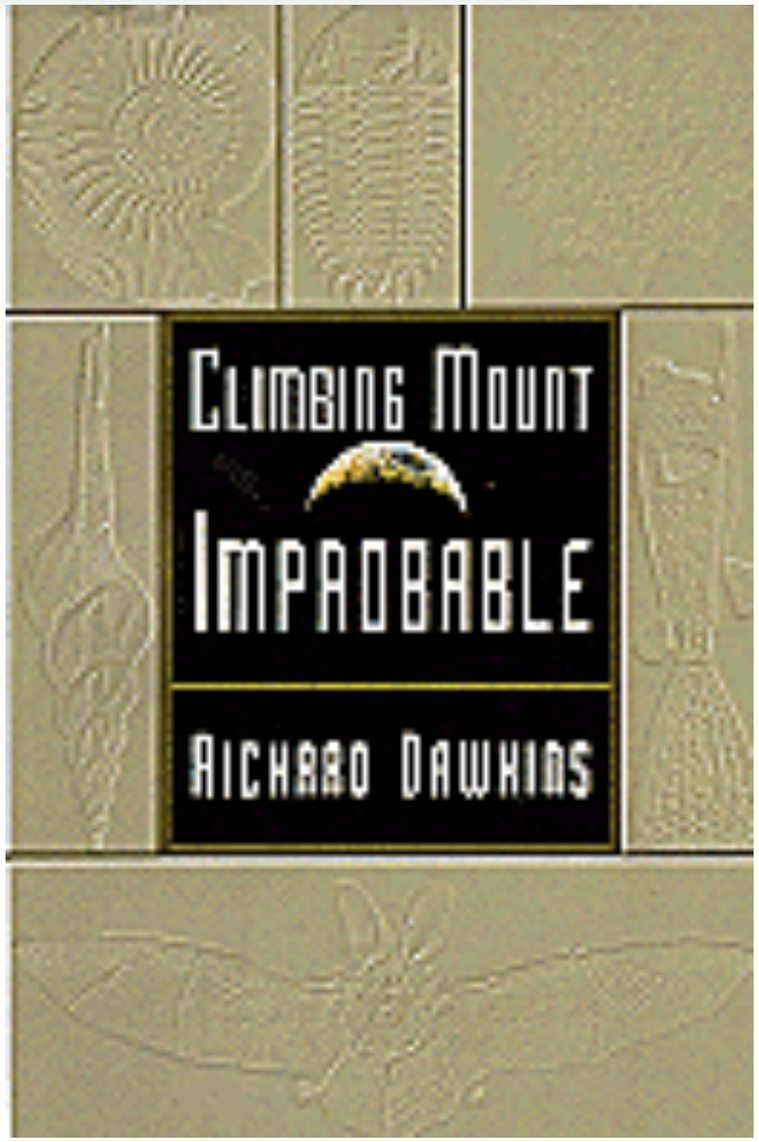
Artificial evolution

- John Holland: Genetic Algorithm, GA
- Ingo Rechenberg: Evolution Strategy, ES
- John Koza: Genetic Programming, GP

Cumulative selection

Richard Dawkins (author of “The selfis gene”)





Watch out!!

the creationists!?!!!

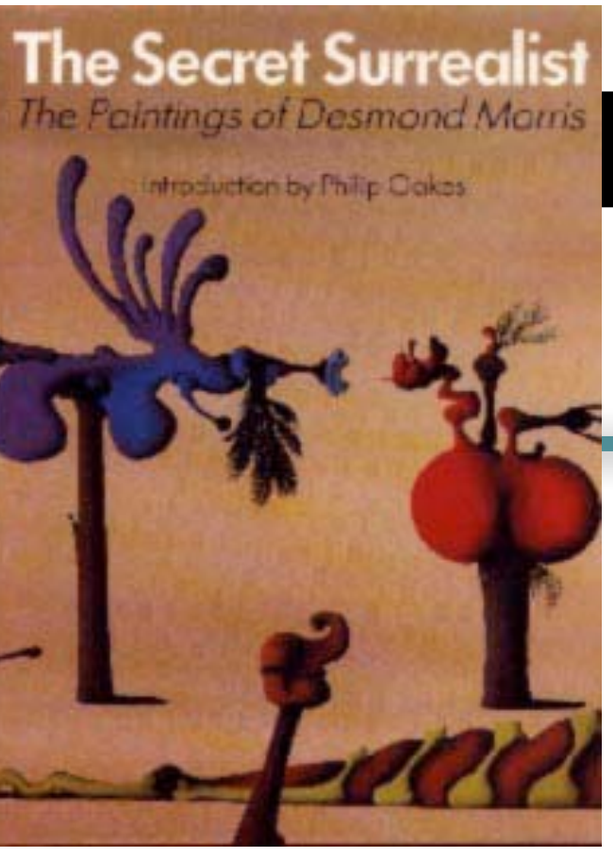
Richard Dawkins:
very outspoken against creationism

Biomorphs
The power of esthetic

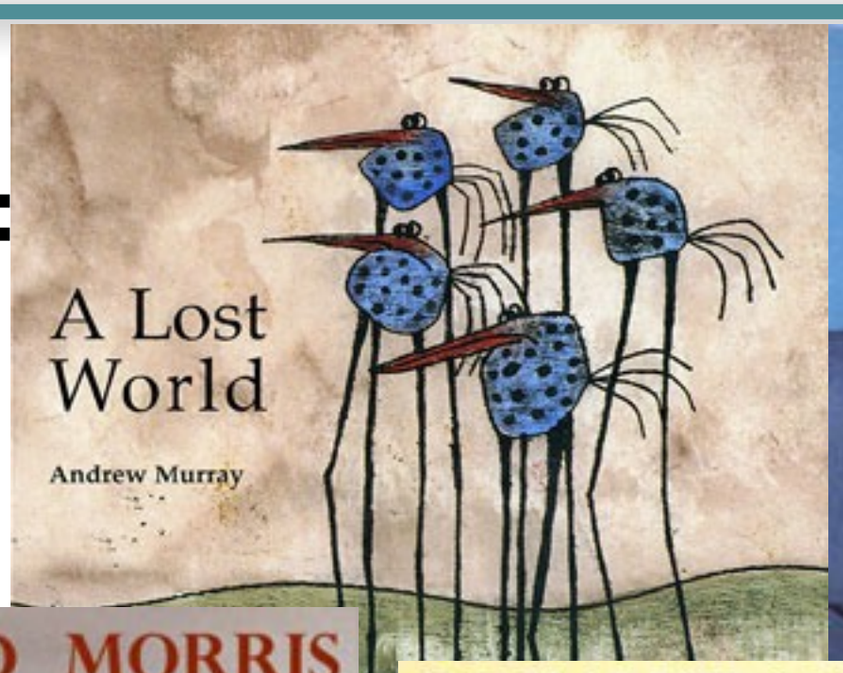
- encoding “creature” in genome (string of numbers):
- expression of “genes” (graphical appearance):
- selection of individuals for “reproduction” (based on “fitness” — esthetic appeal)

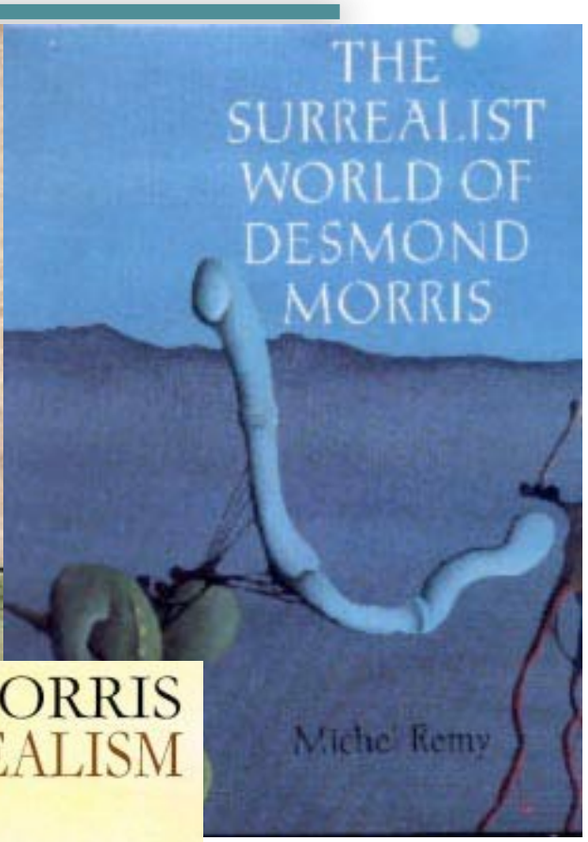
http://suhep.phy.syr.edu/courses/mirror/biomorph/

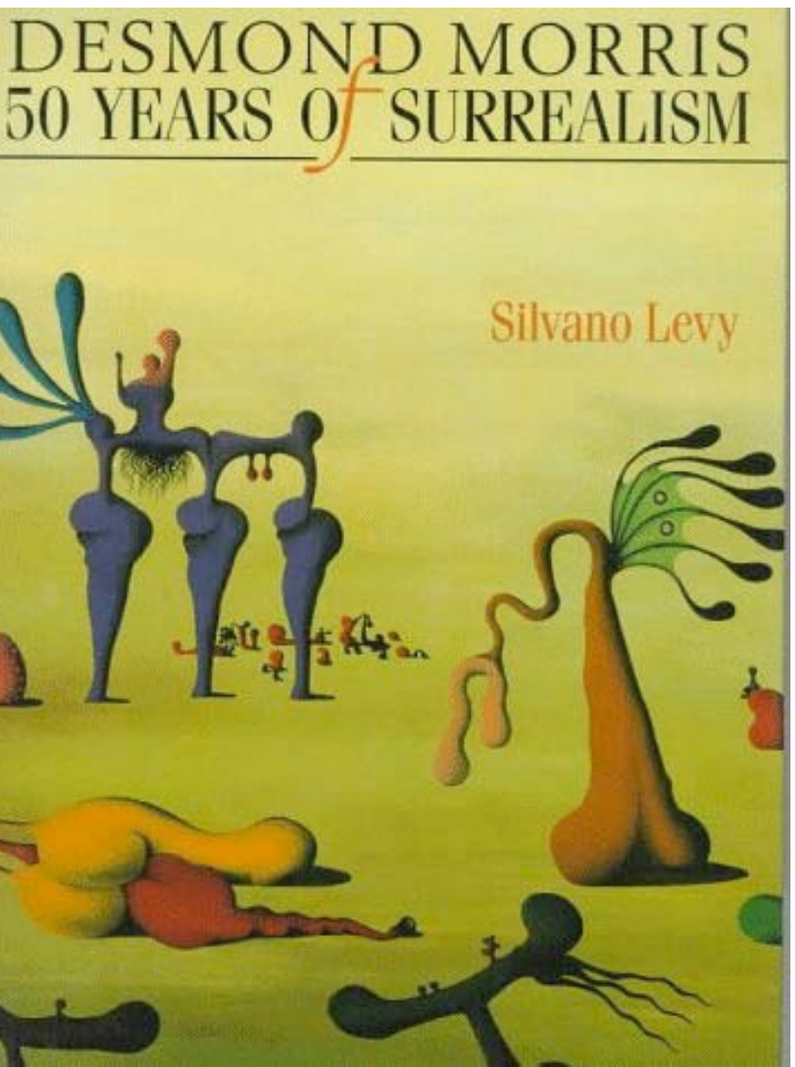
Biomorphs: by surrealist painter Desmond Morris

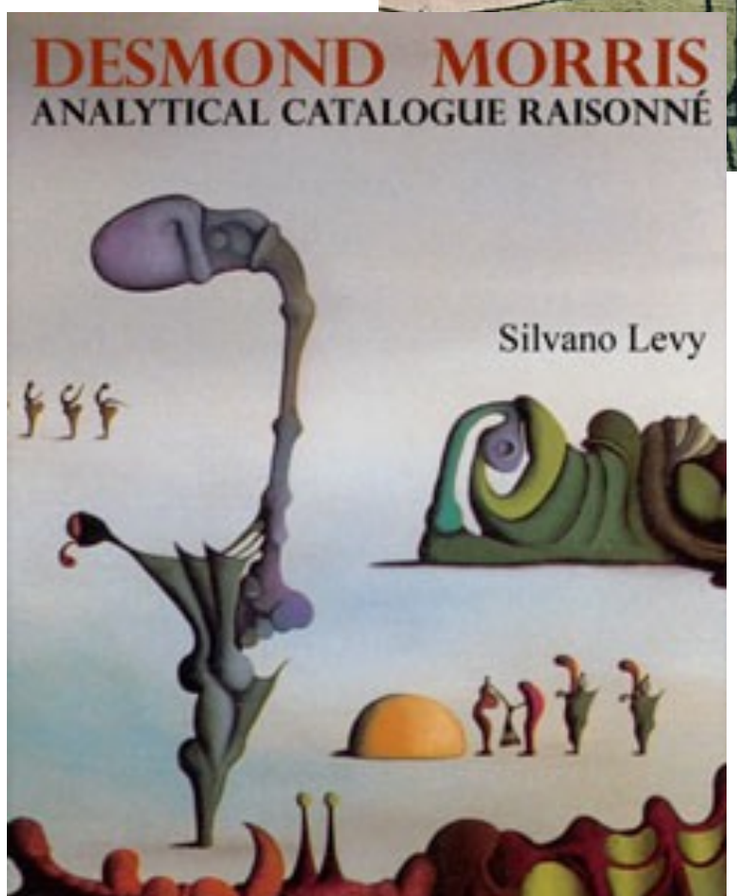


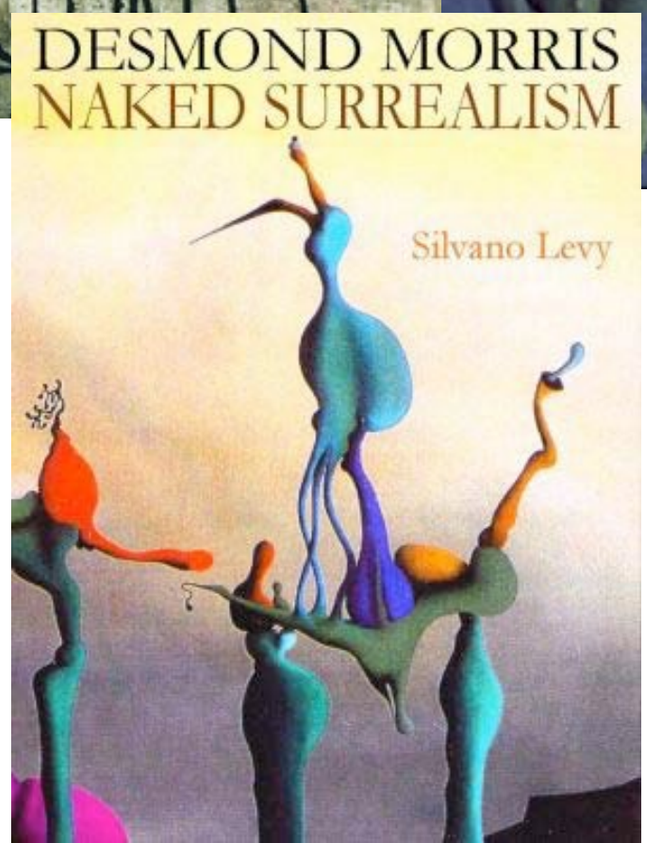
exhibitions: 1948 - 2008







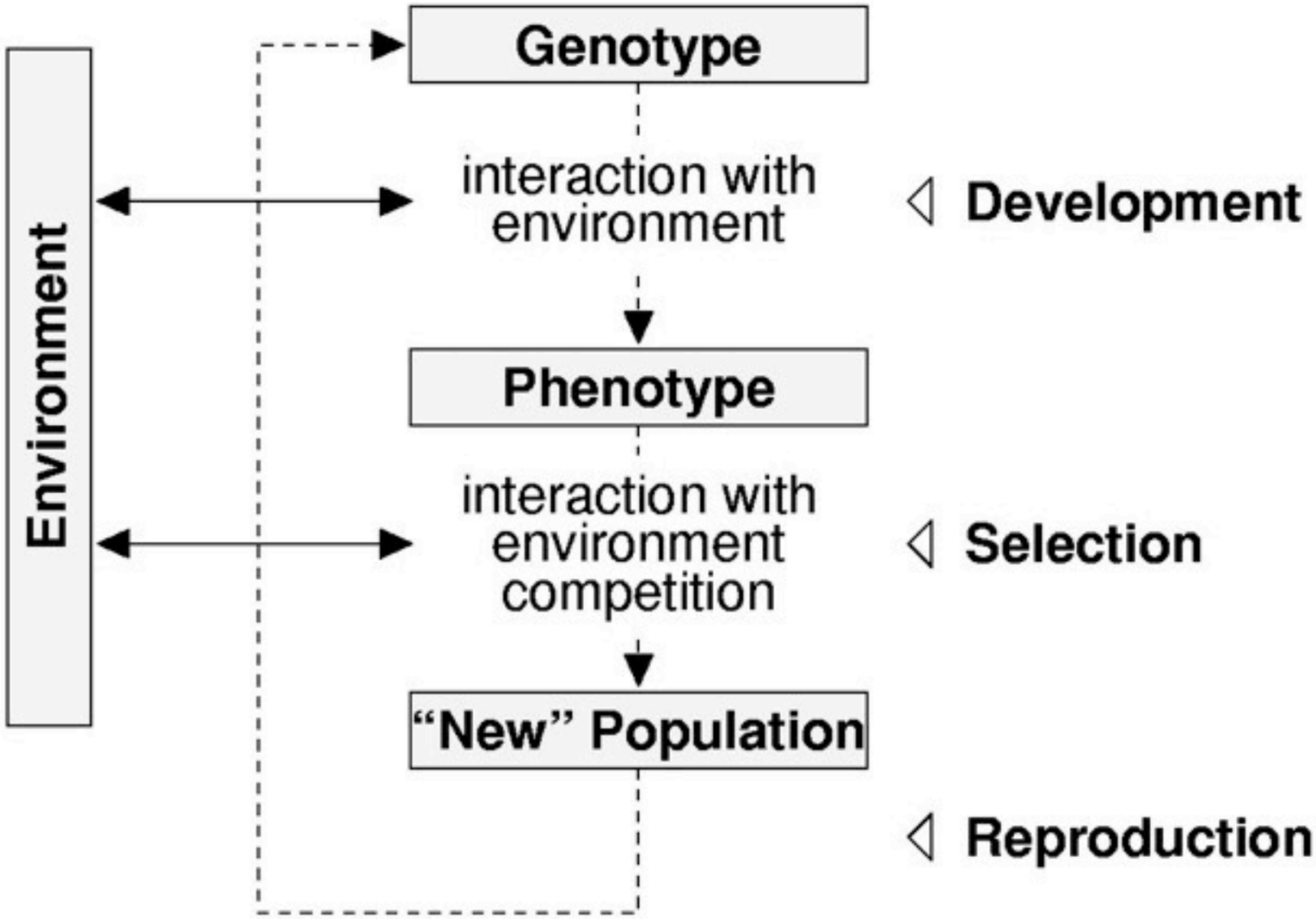




Biomorphs
Encoding in genome

- “genes” 1-8: control of overall shape (direction, length of attachment)
- “gene” 9: depth of recursion
- “genes” 10-12: color
- “gene” 13: number of segmentations
- “gene” 14: size of separation of segments
- “gene” 15: shape for drawing (line, oval,

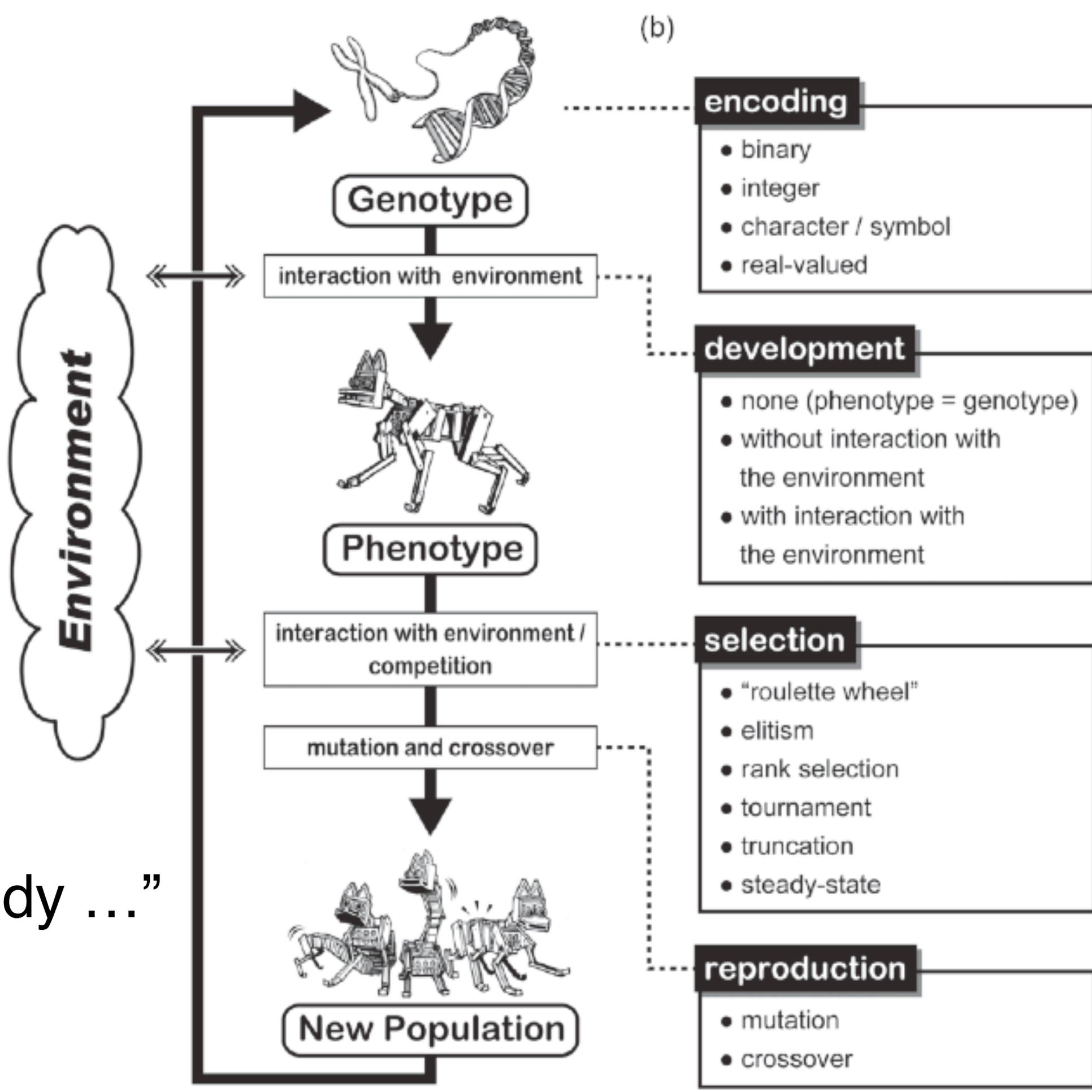
The“grand evolu-tionary



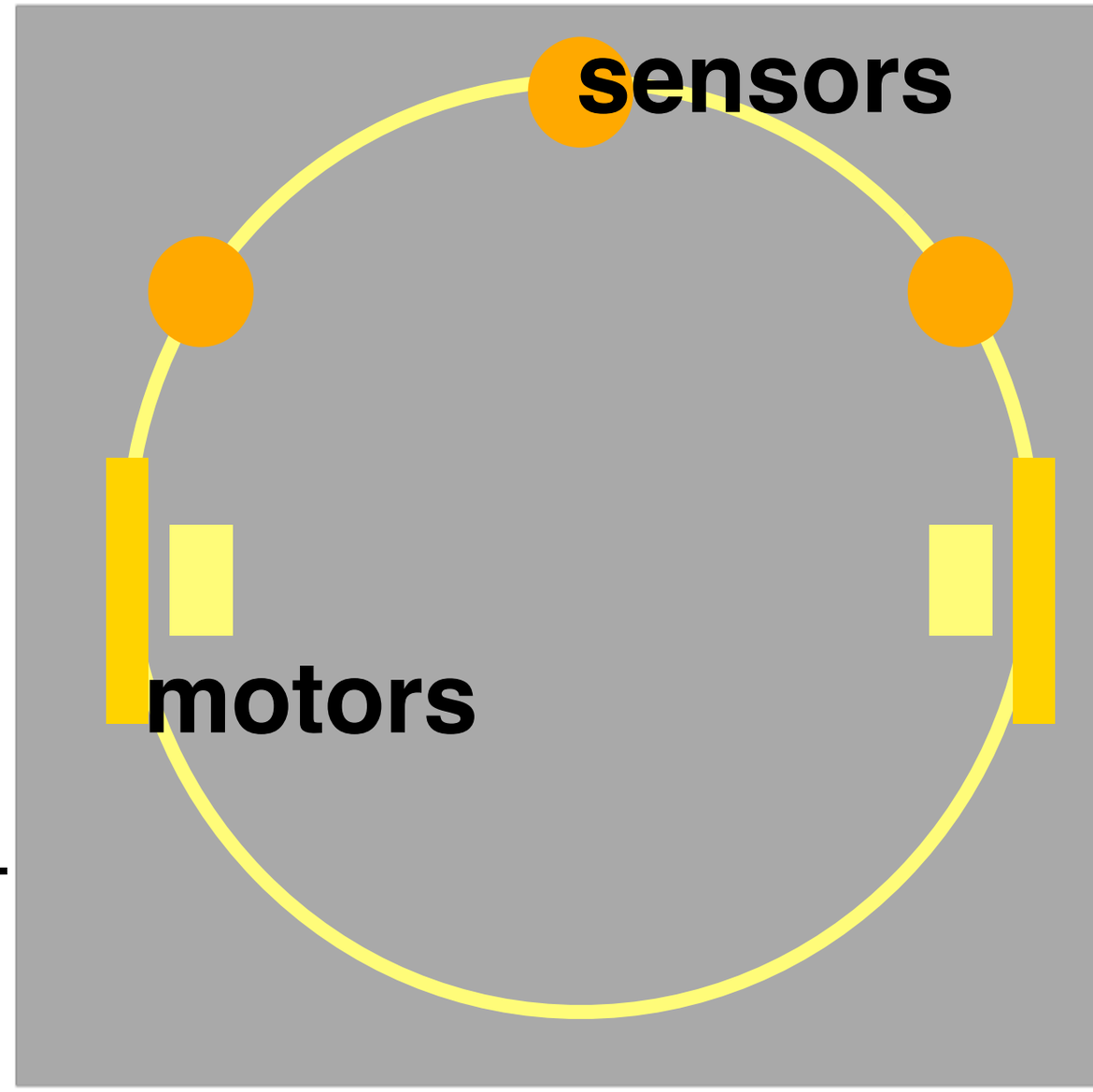
encoding	development	selection	reproduction
• binary • many-character • real-valued	• no development (phenotype = genotype) • development with and without interaction with the environment	• “roulette wheel” • elitism • rank selection • tournament • truncation • steady-state	• mutation • crossover

Basic cycle for artificial evolution

from
“How the body …”



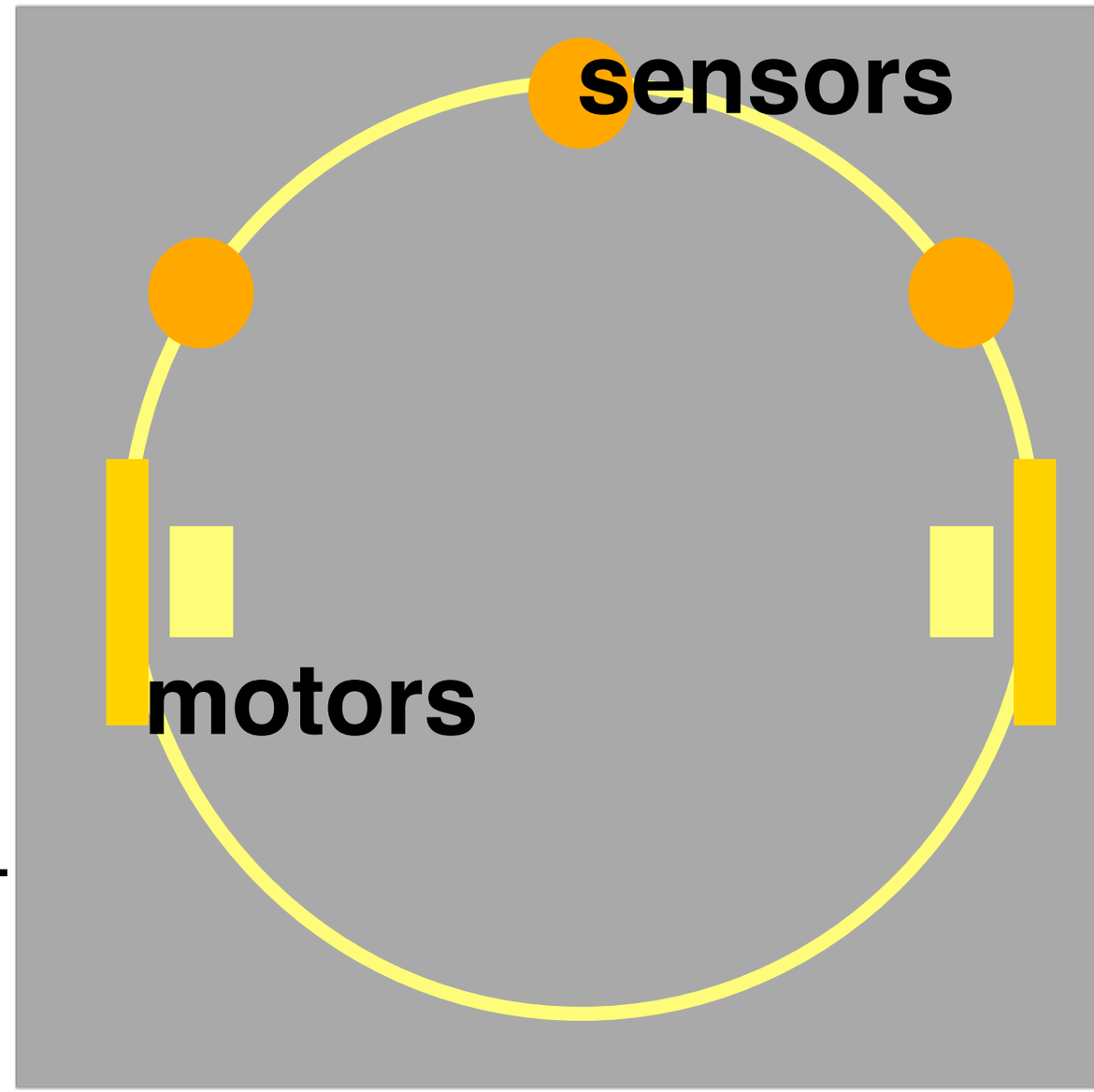
Evolving a neural controller



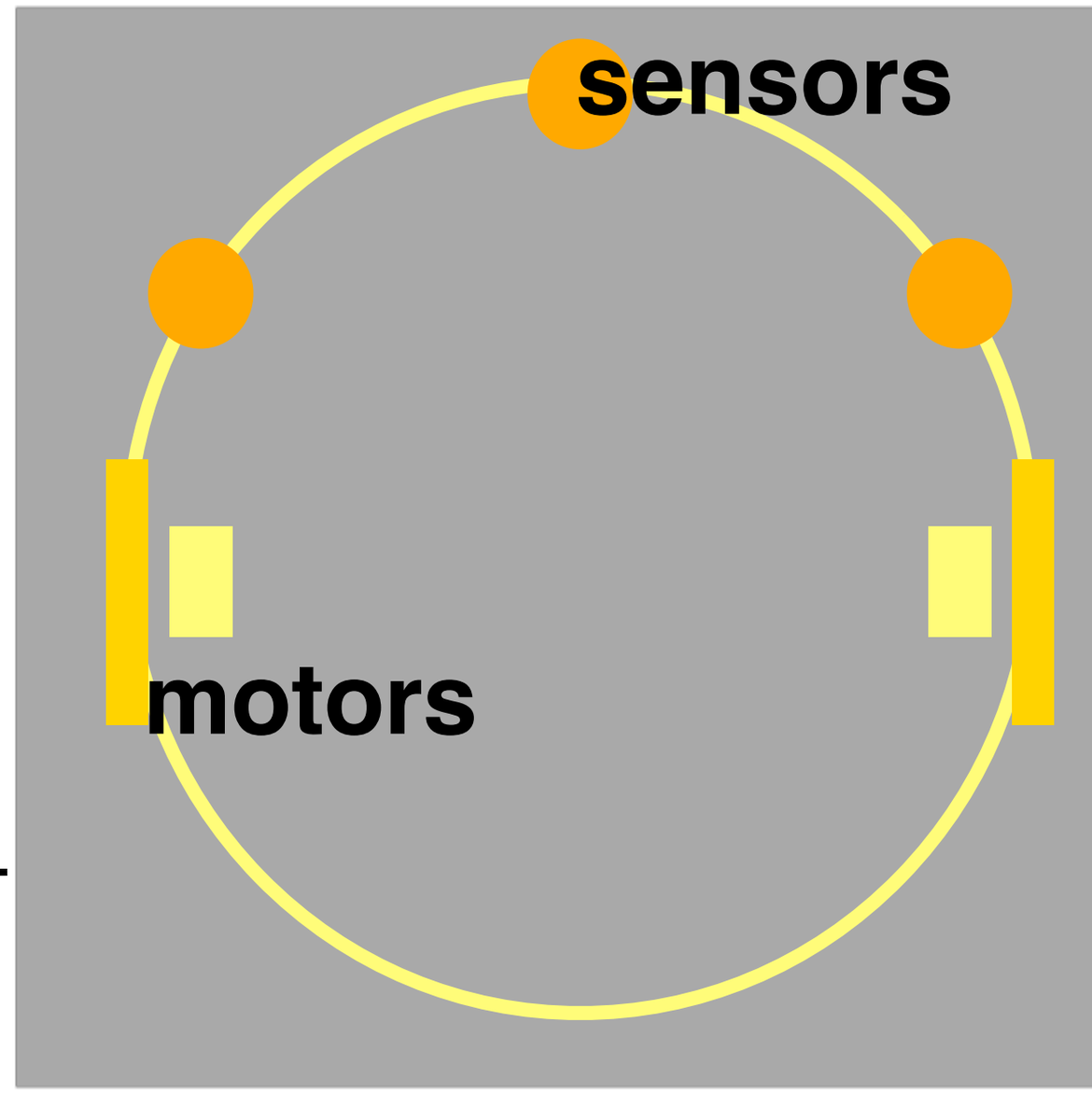
Evolving a neural controller

What do we need to specify?

—>

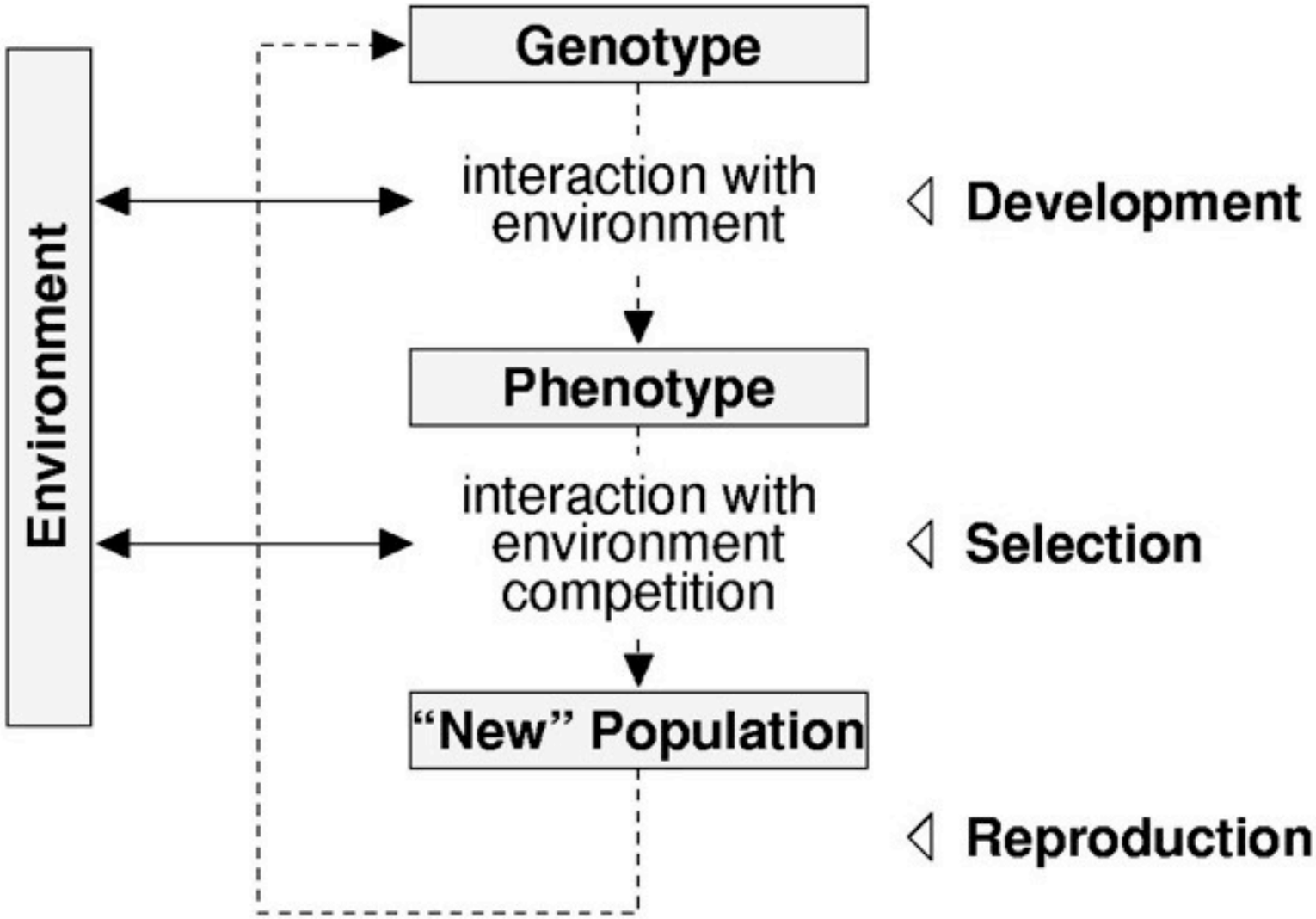


Encoding in genome



	1	2	3	4	5	6
initial genome	001101010010011110101010					
encoded weights	-.3	-.17	-.37	.03	.17	.17

The“grand evolu-tionary



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Fitness function and selection

suggestions? —> Chiba

encoding	development	selection	reproduction
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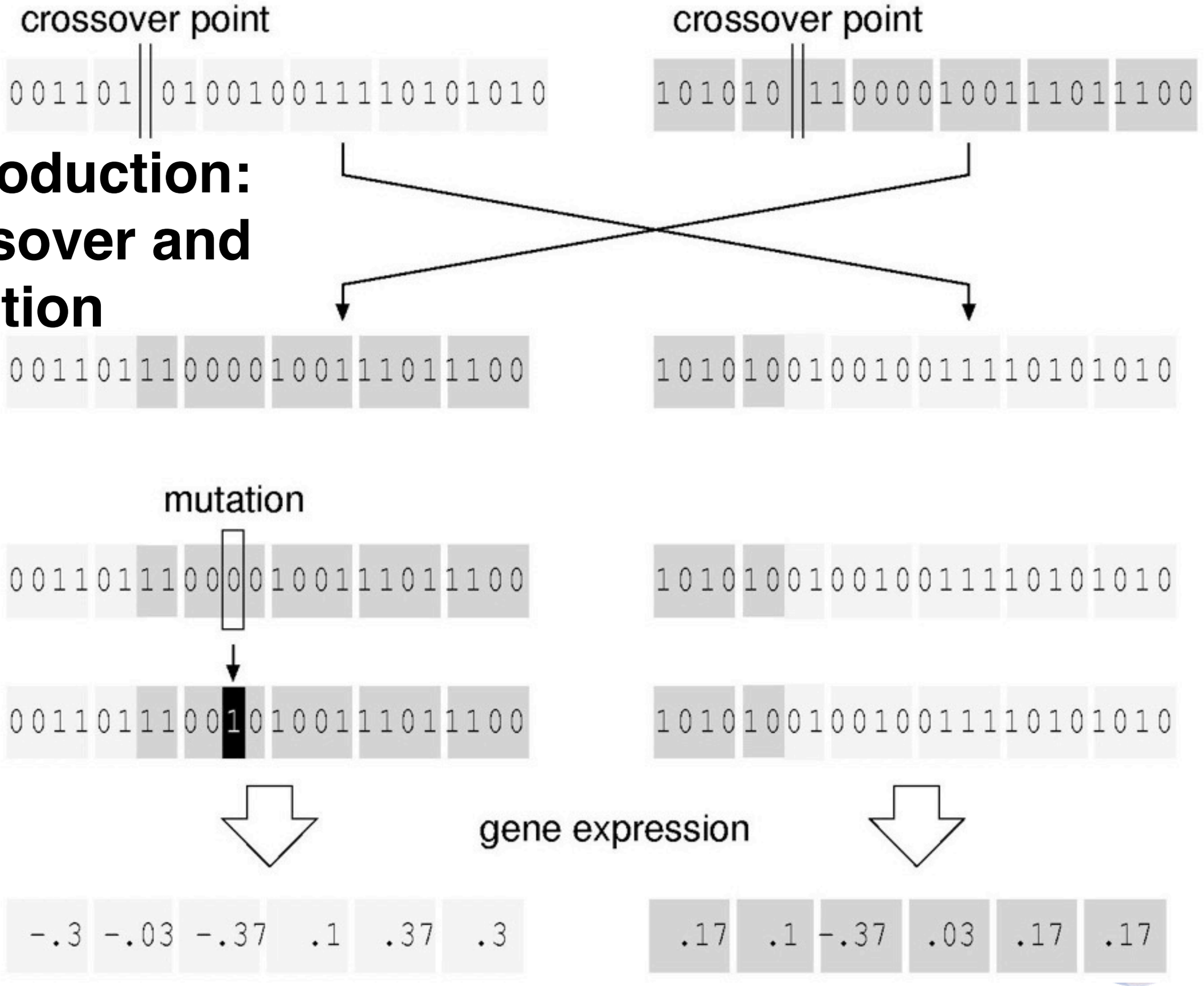
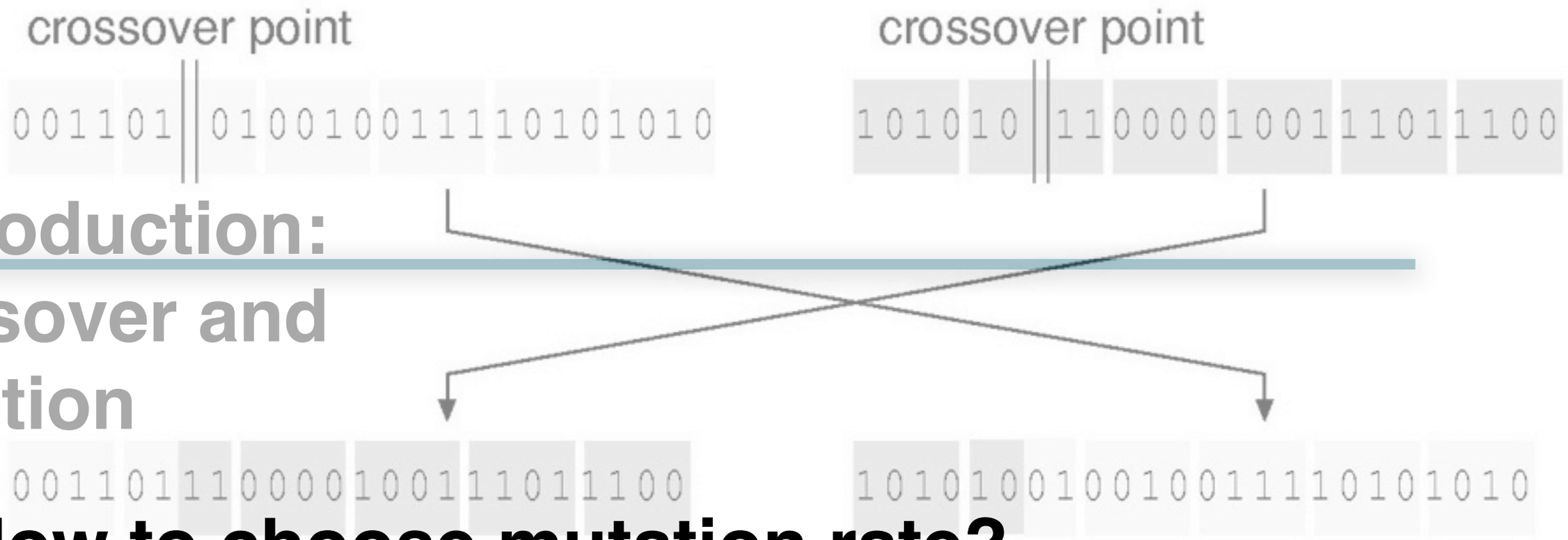
Reproduction: crossover and mutation



Reproduction: crossover and mutation



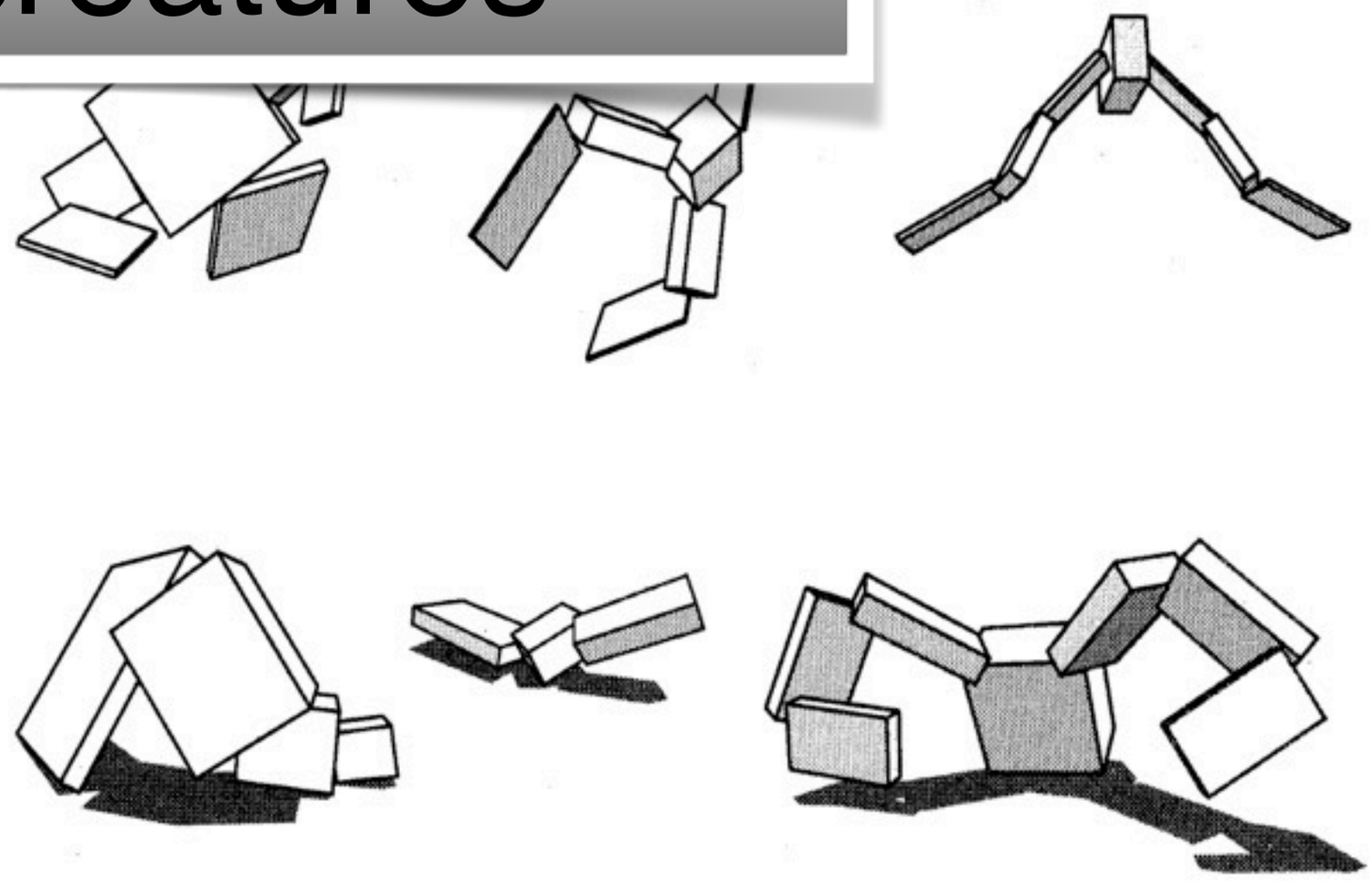
How to choose mutation rate?

Approaches to evolutionary robotics

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

Evolving morphology and control: Karl Sims's

Video "Karl Sims's evolved creatures"



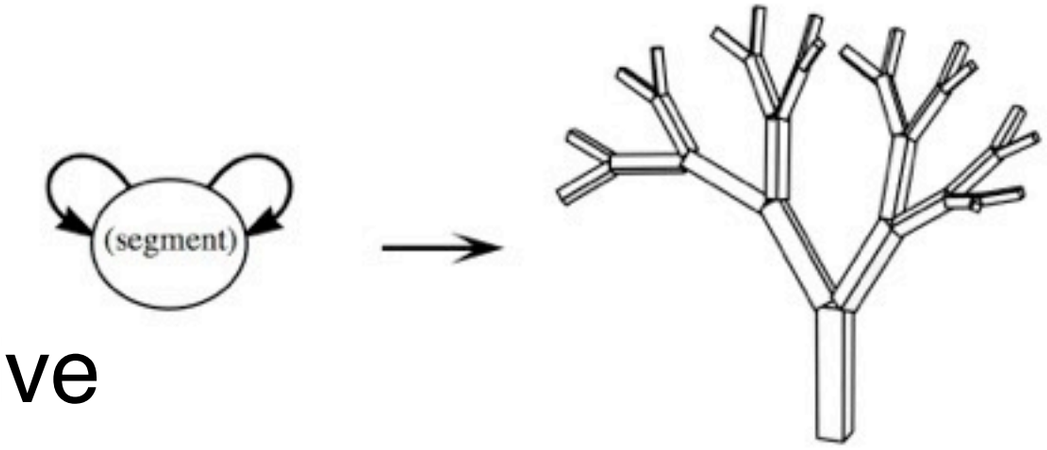
Parameterization of morphology

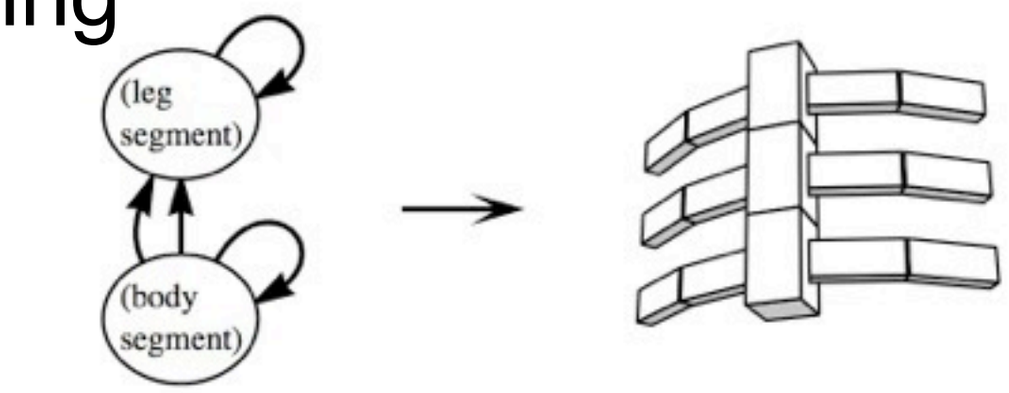
encoding in genome "genotype"

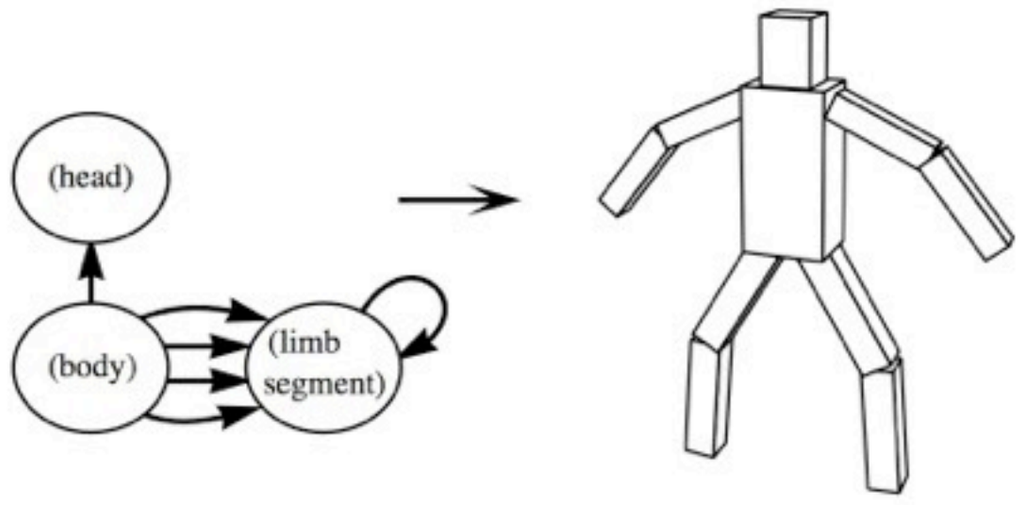
development

embodied agent "phenotype"

recursive encoding







Parameterization of morphology

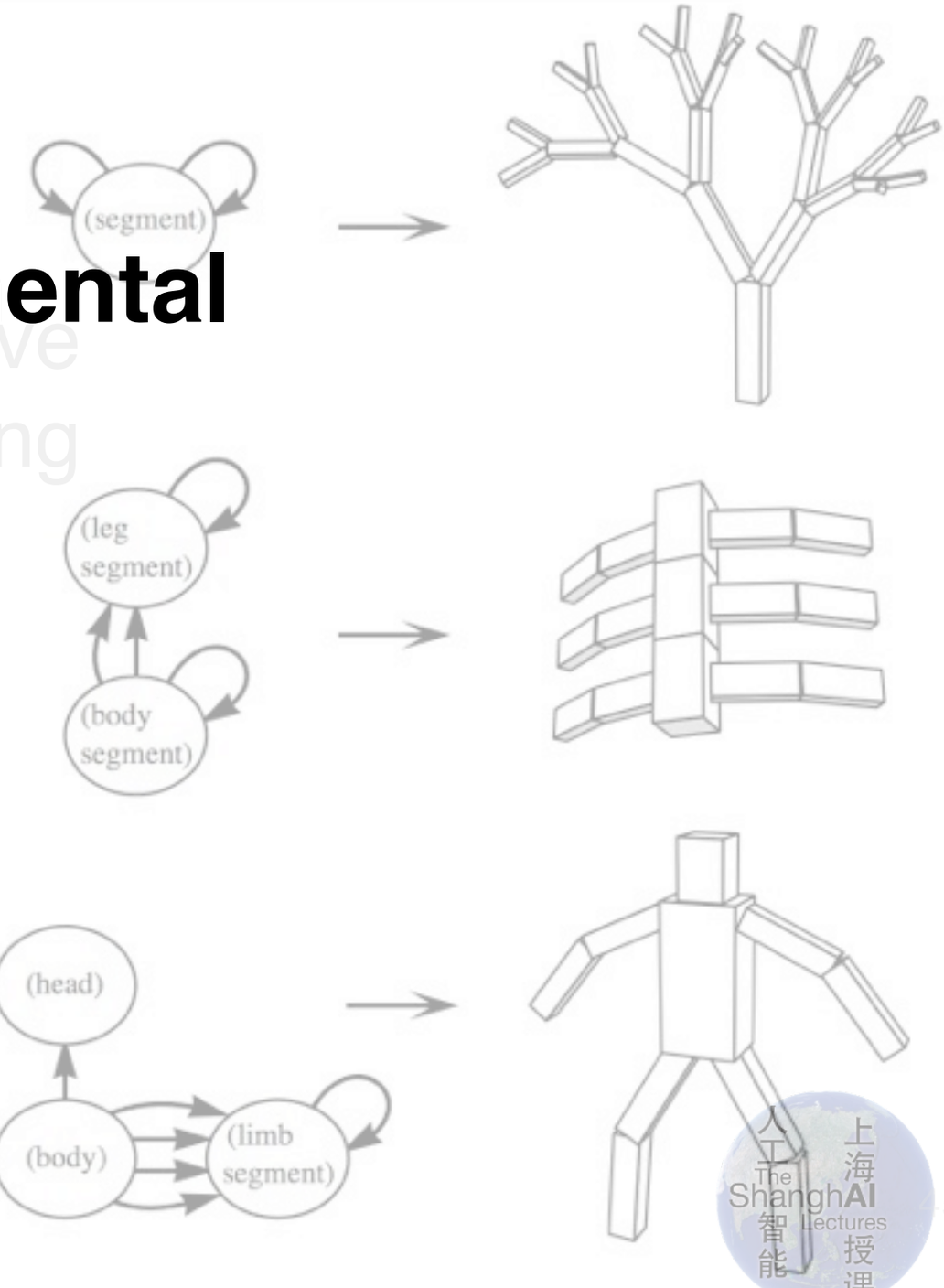
encoding in genome "genotype"

development

embodied agent "phenotype"

recursive encoding

characterizing the "developmental process"

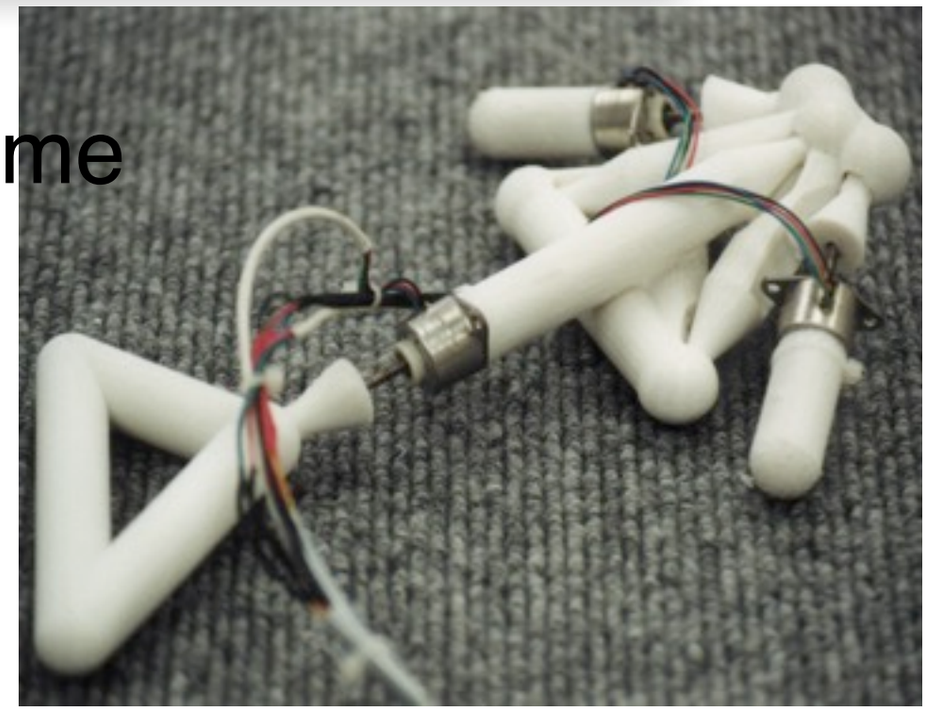


New version: Golem (Lipson and Pollack)

representation of morphology in genome

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

  (recursive encoding)



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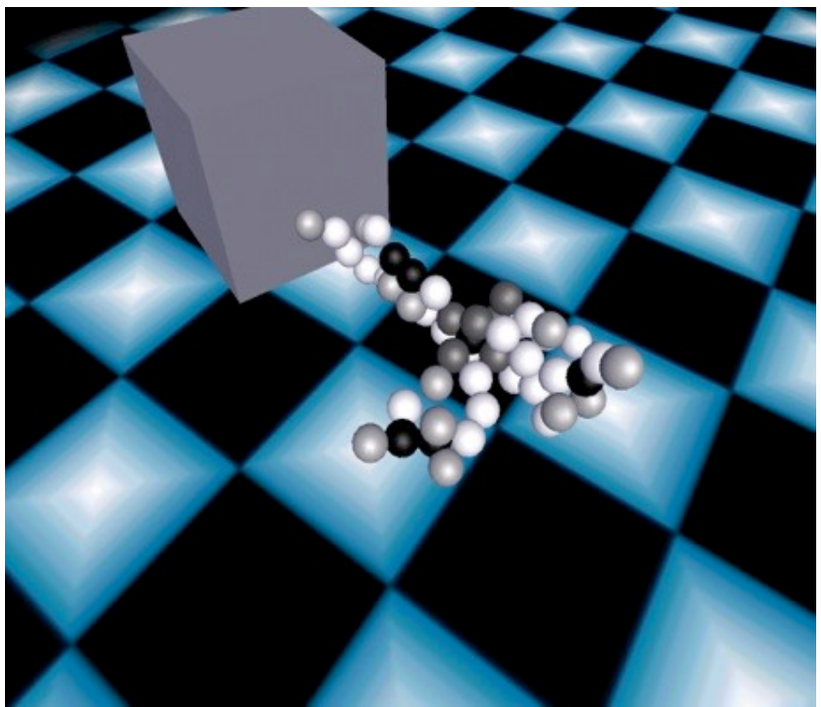
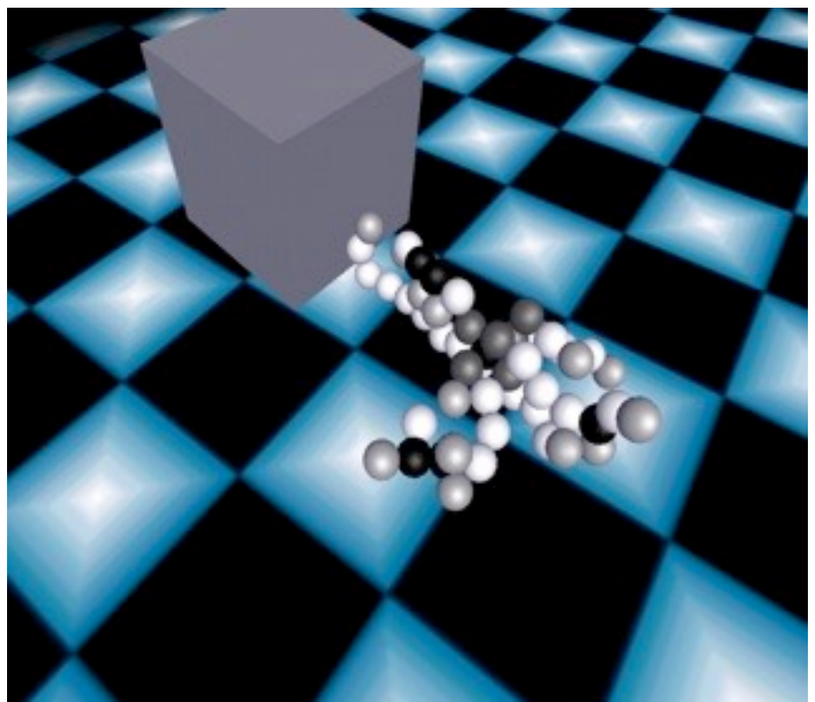
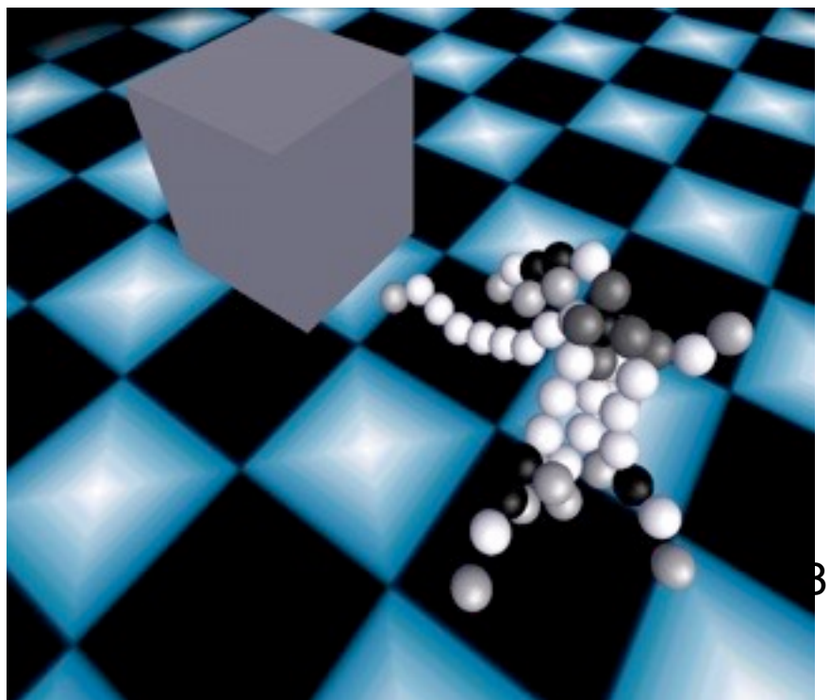
(recursive encoding)

Golem as the first self-evolving machine in history

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

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

The Growth Phase

t = 42

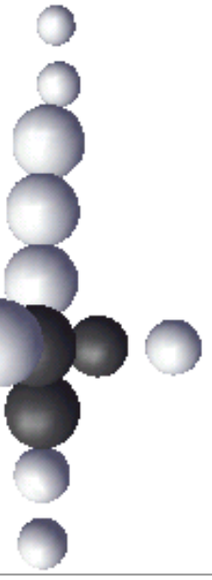
t = 84

t = 125

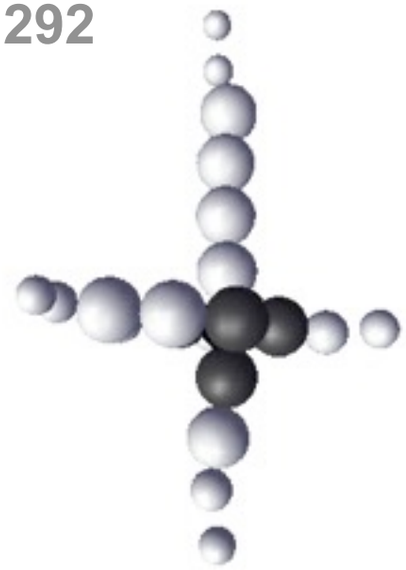
t = 167

t = 208

t = 250



t = 292



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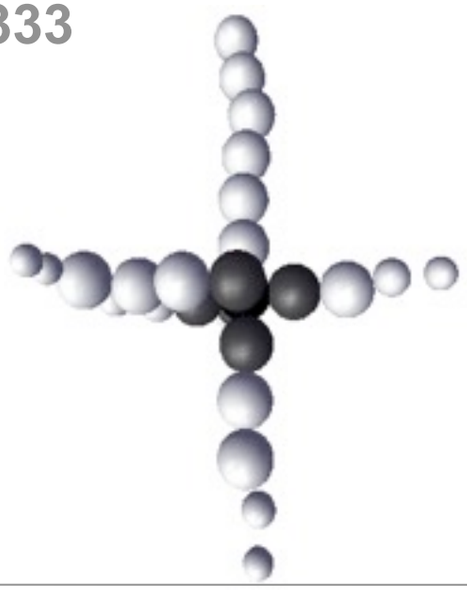

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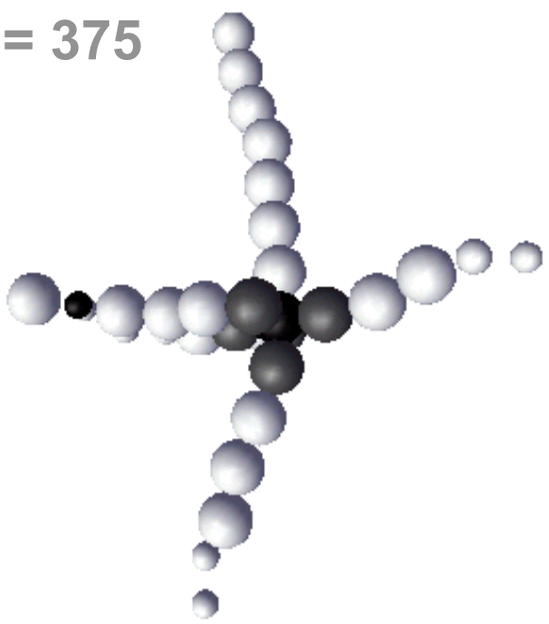

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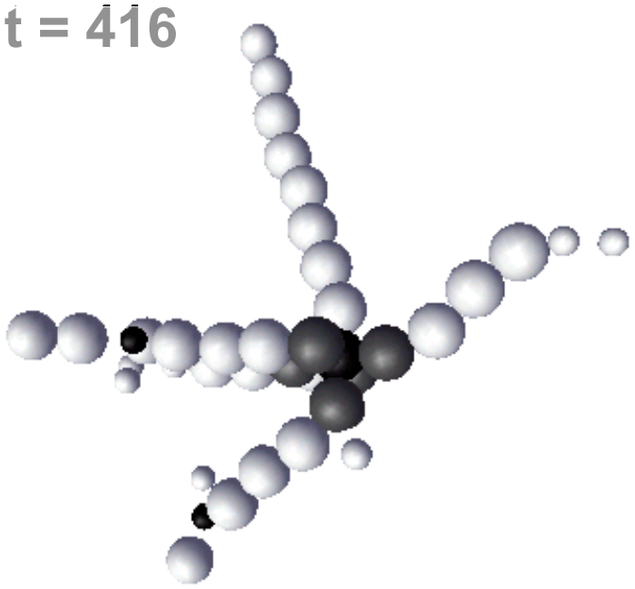

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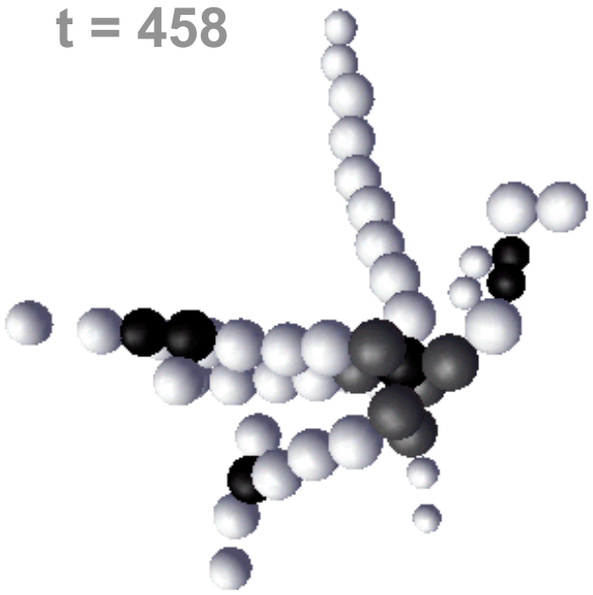

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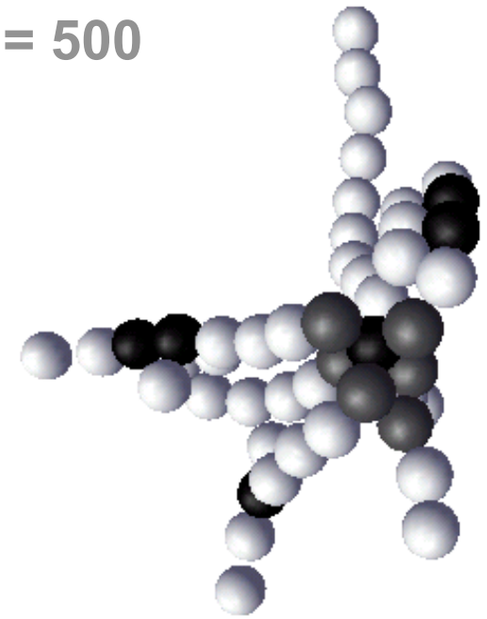
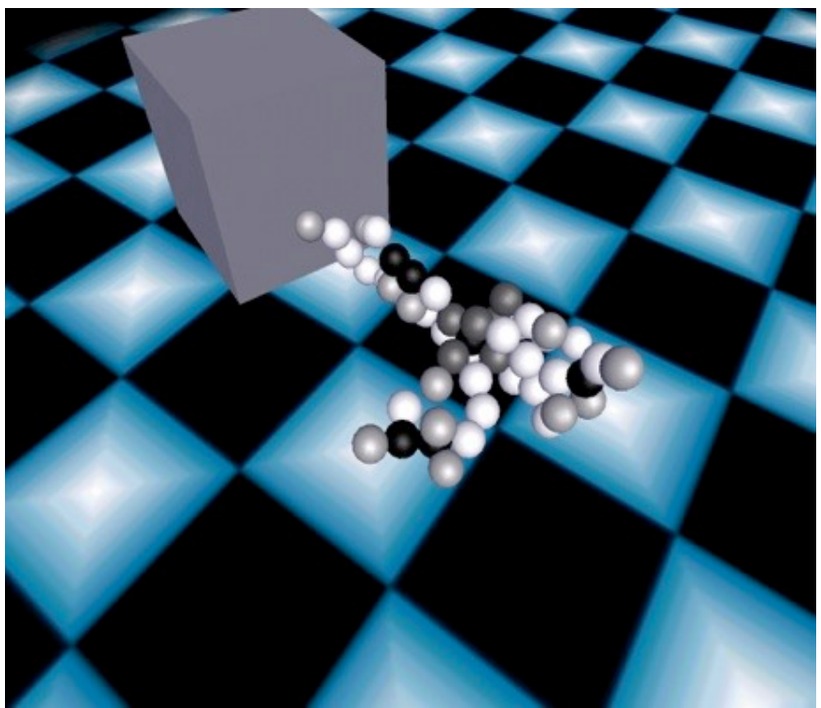
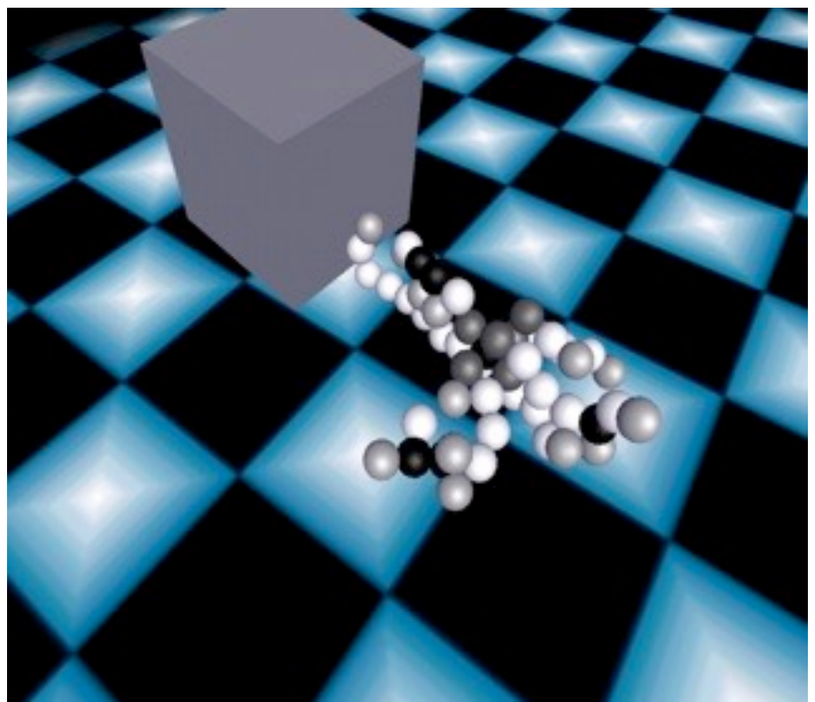
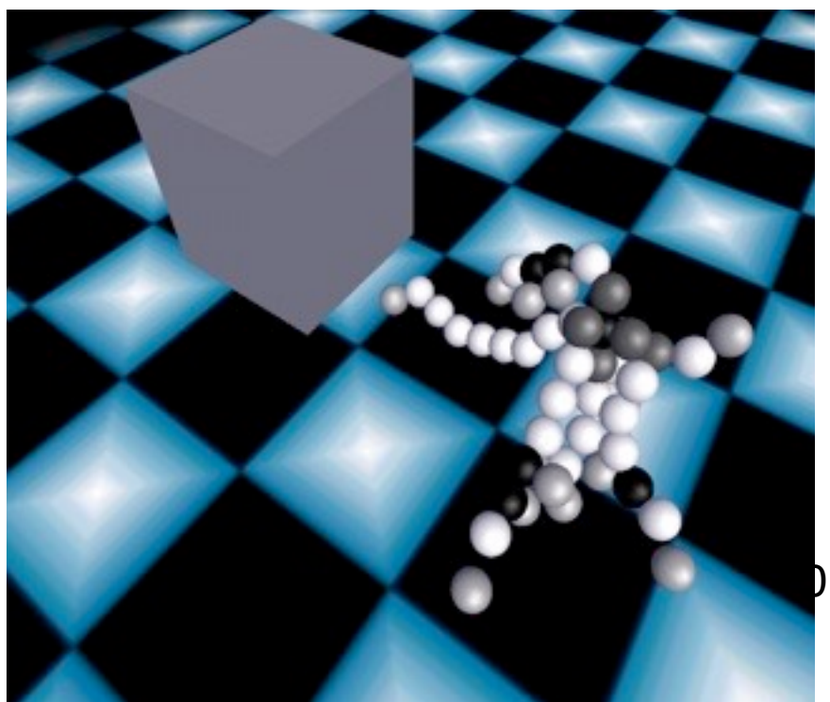
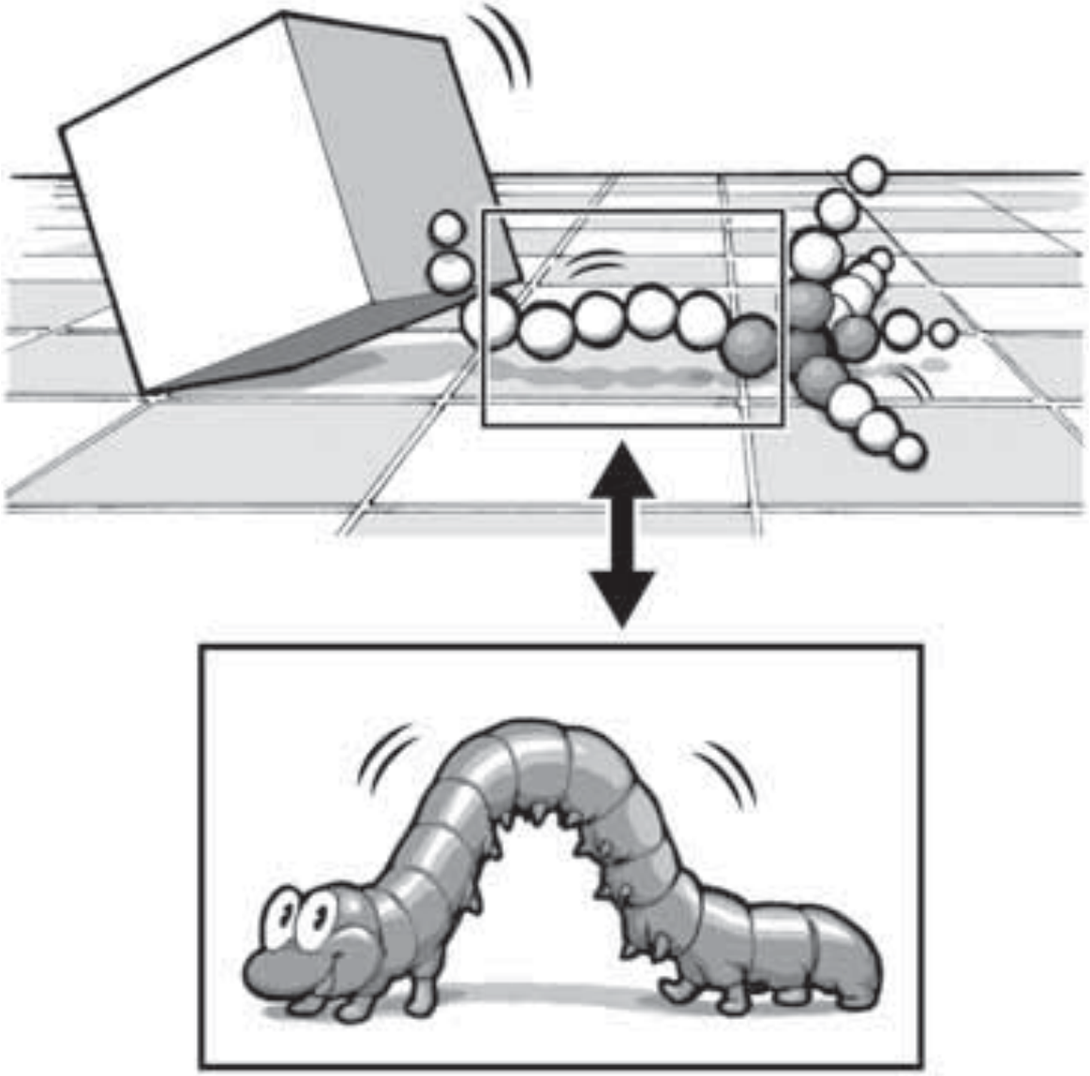


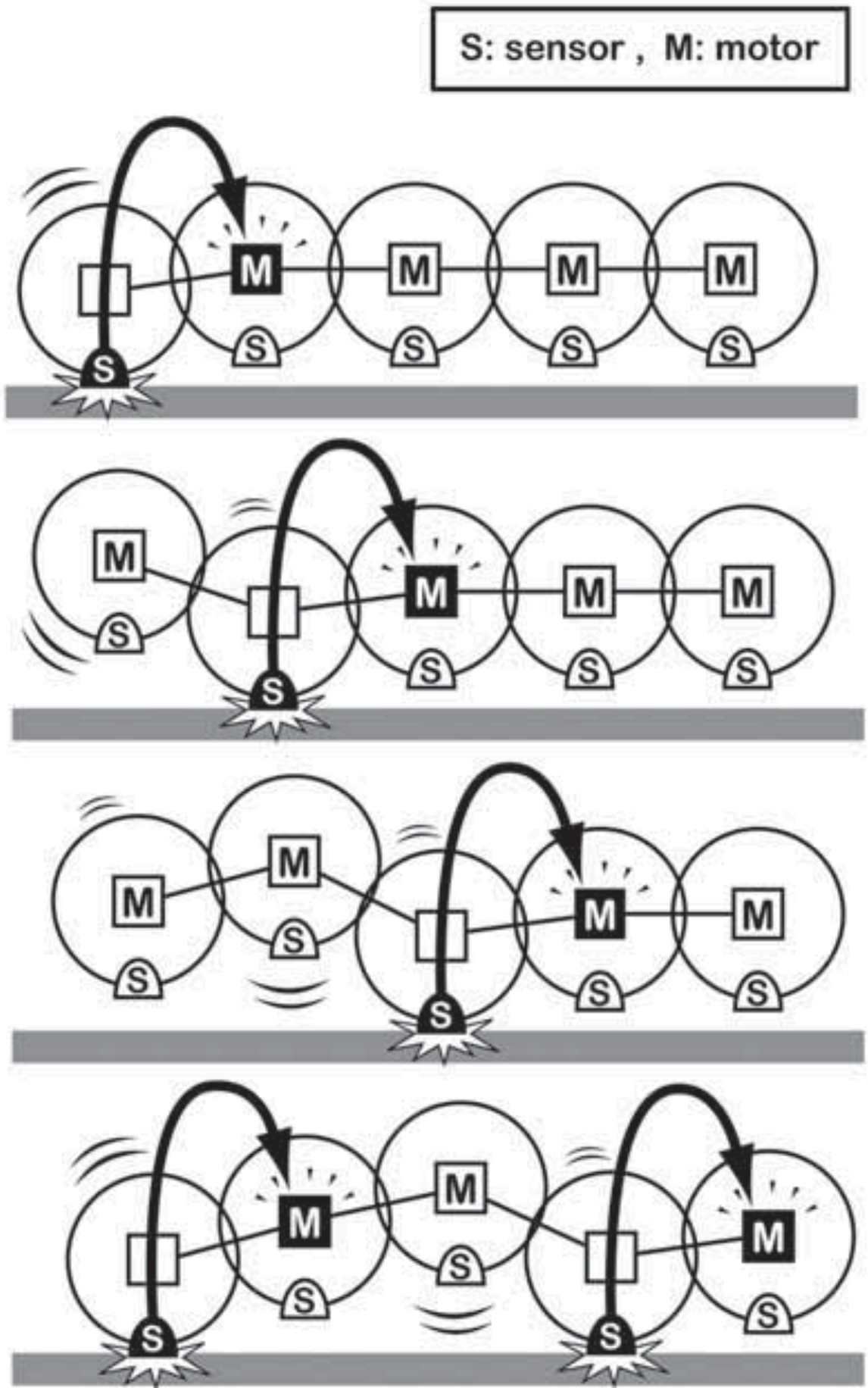
Evolution of a “block pusher” (“Artificial Ontogeny”)

- development (morphogenesis) embedded
- Video “Evolution of block pushers”

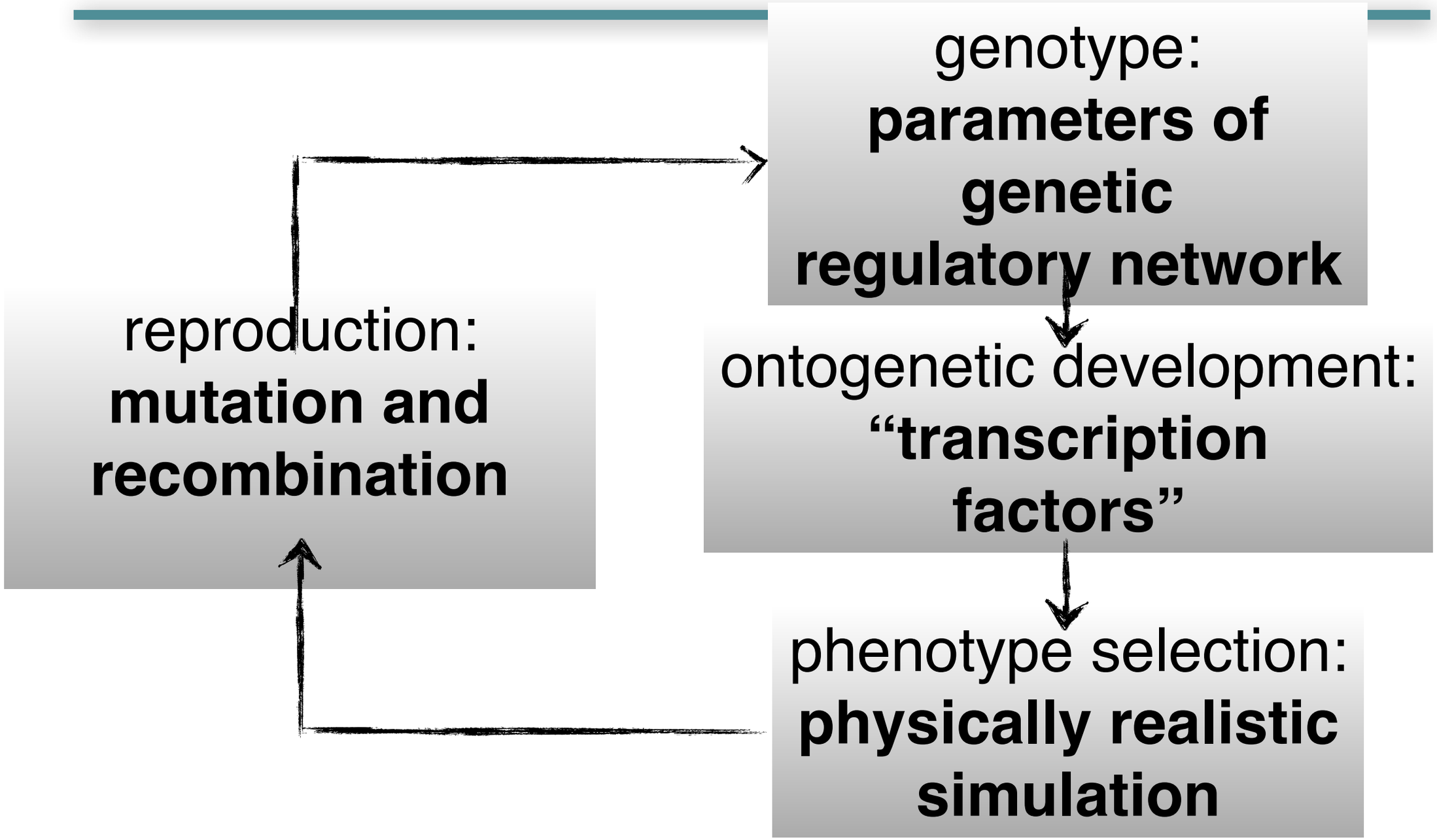




Inchword methoc of locomotion



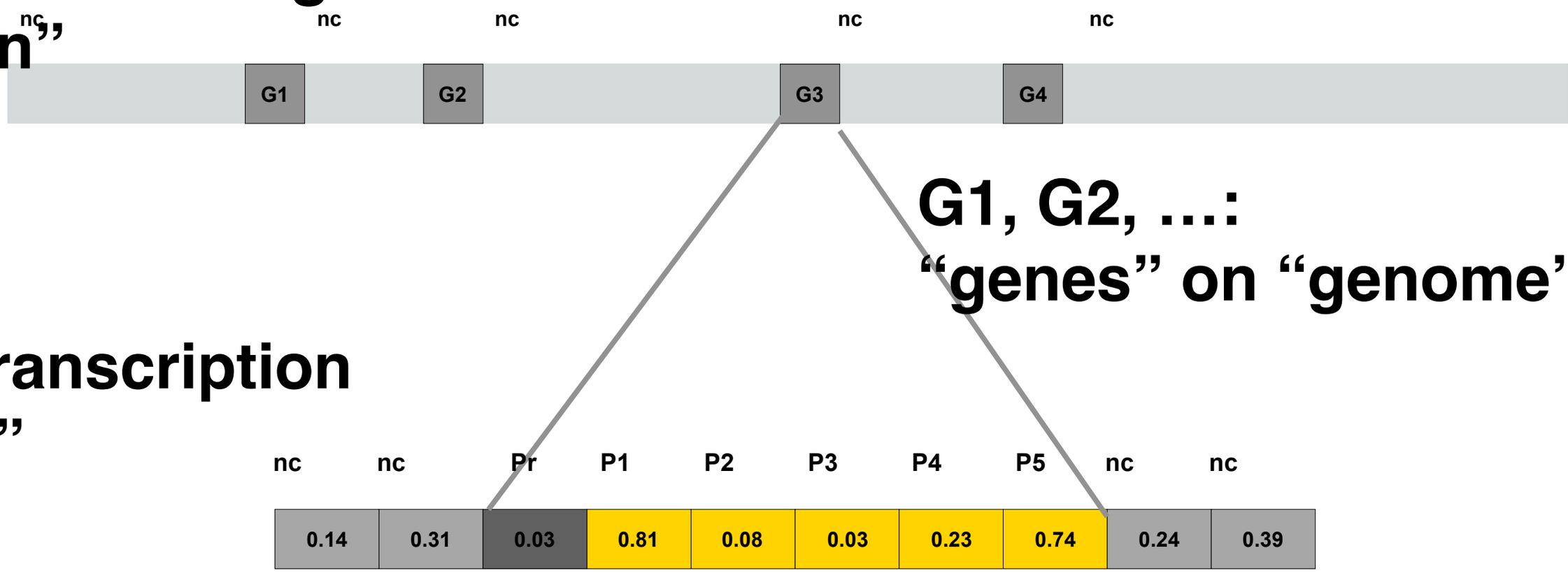


Bongard's evolutionary scheme



Representation of “gene”

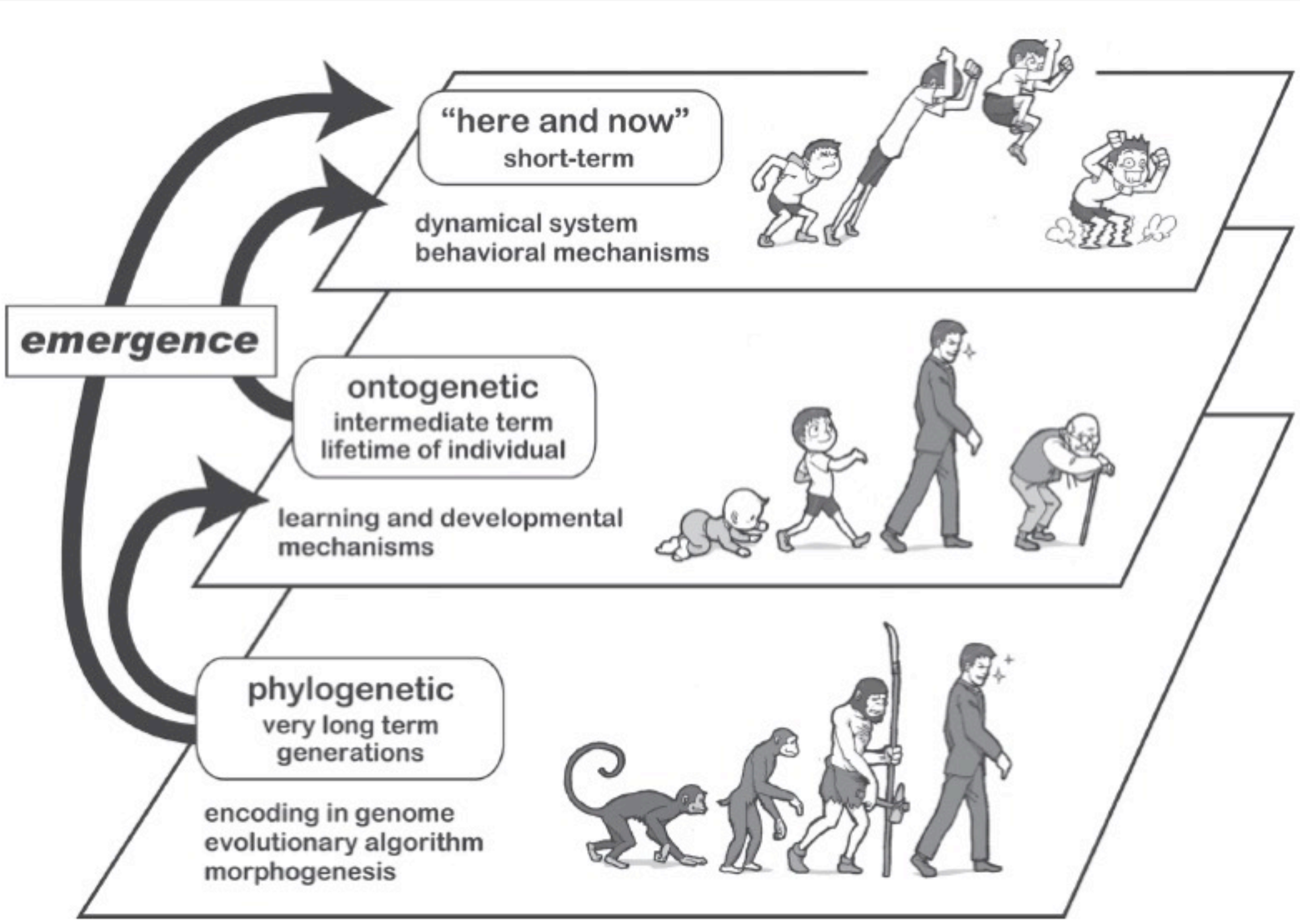
nc: “non-coding region”



TF: “transcription factor”

Details: see additional slide
materials for self-study

Time scales tightly intertwined



Design principles for artificial evolution

Principle 1: Population

Principle 2: Cumulative selection and self-organization

Principle 3: Brain-body co-evolution

Principle 4: Scalable complexity

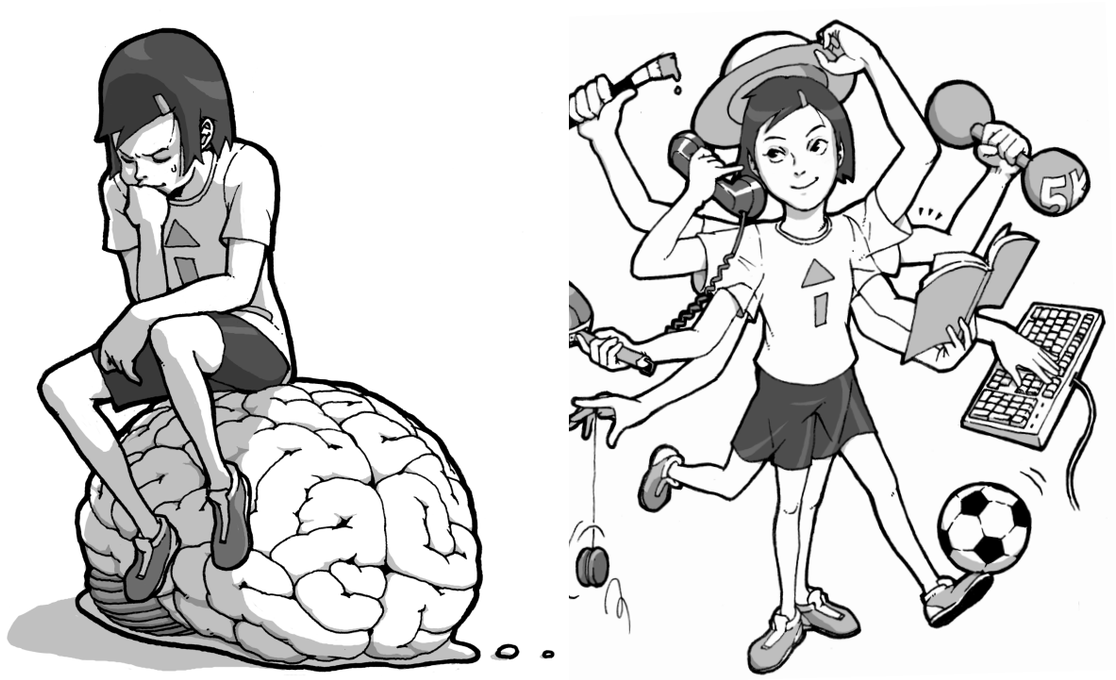
Principle 5: Evolution as a fluid process

Principle 6: Minimal designer bias

End of lecture 5

Thank you for your attention!

stay tuned for the guest lecture



Assignments for next week

- Next lecture on 1 December 2016: “Embodied Intelligence”.
- Read chapters 8, 9 of “How the body …”
- Additional study materials (on web site)

End of lecture 5

Thank you for your attention!

stay tuned for lecture 6 “Morphological Computation, Self-Organization of Behaviors and Adaptive Morphologies”

Fabio Bonsignorio
Prof,the BioRobotics Institute, SSSA
CEO and Founder Heron Robots
Santander - UC3M Chair of Excellence 2010

Research interests

- embodied intelligence, cognition/AI and robotics

- experimental methods in Robotics and AI

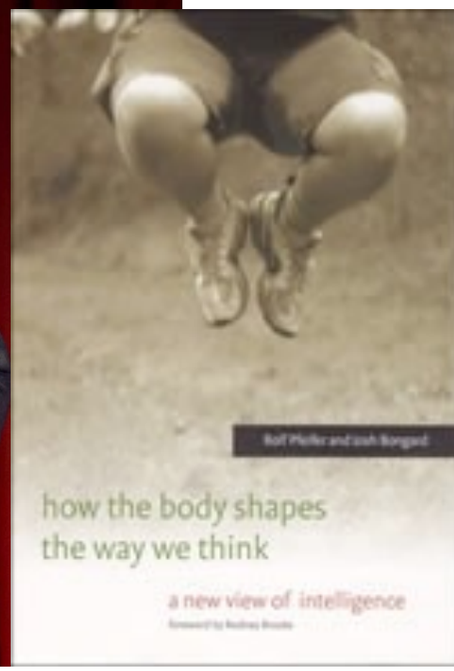
- Advanced approaches to Industry 4.0

- synthetic modeling of life and cognition

- novel technologically enabled approaches to higher education and lifelong learning

The ShanghAI Lectures
2013-2016

Rolf Pfeifer
Prof,
Institute for Academic Initiatives, Osaka University, Japan
Dept. of Automation, Shanghai Jiao Tong University, China
Prof Em.,Former Director AI Lab, Univ. of Zurich

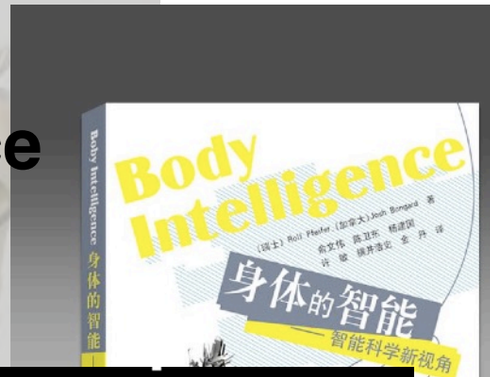


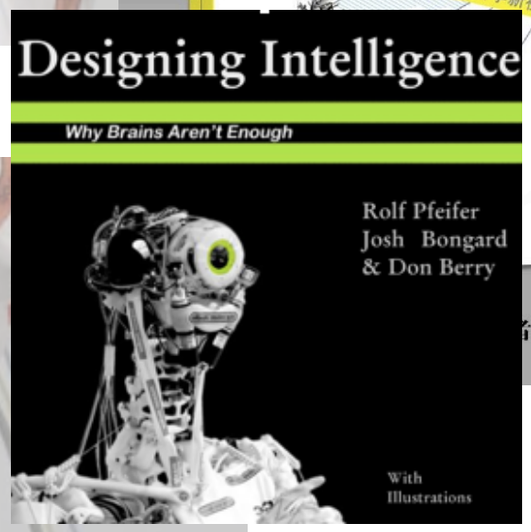
Research interests

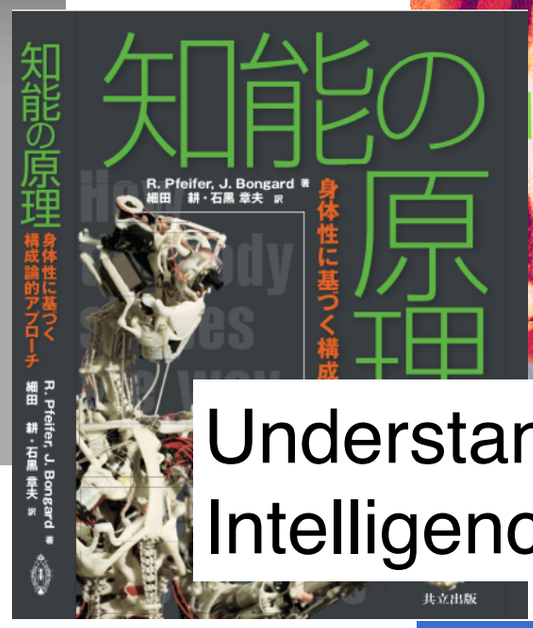
- **embodied intelligence**
- **bio-inspired robotics**
- **self-organization and emergence**
- **educational technologies**

How the body shapes the way we think

MIT Press







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Understanding Intelligence

DI BIOROBOTICA

Scuola Superiore Sant'Anna