
人工智能
The ShanghAI Lectures
上海授课

The ShanghAI Lectures

An experiment in global teaching

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Today from the University Carlos III of Madrid
Spain

欢迎您参与

“来自上海的人工智能系列讲座”

Lecture 7

Design principles for intelligent systems

28 November 2013

Today's topics

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

Short recap

- The classical approach: Cognition as computation
- Successes and failures of the classical approach
- Some problems of the classical approach

Hard to agree on definitions, arguments

- **necessary and sufficient conditions?**
- **are robots, ants, humans intelligent?**

more productive question:

“Given a behavior of interest, how to implement it?”

Measuring intelligence

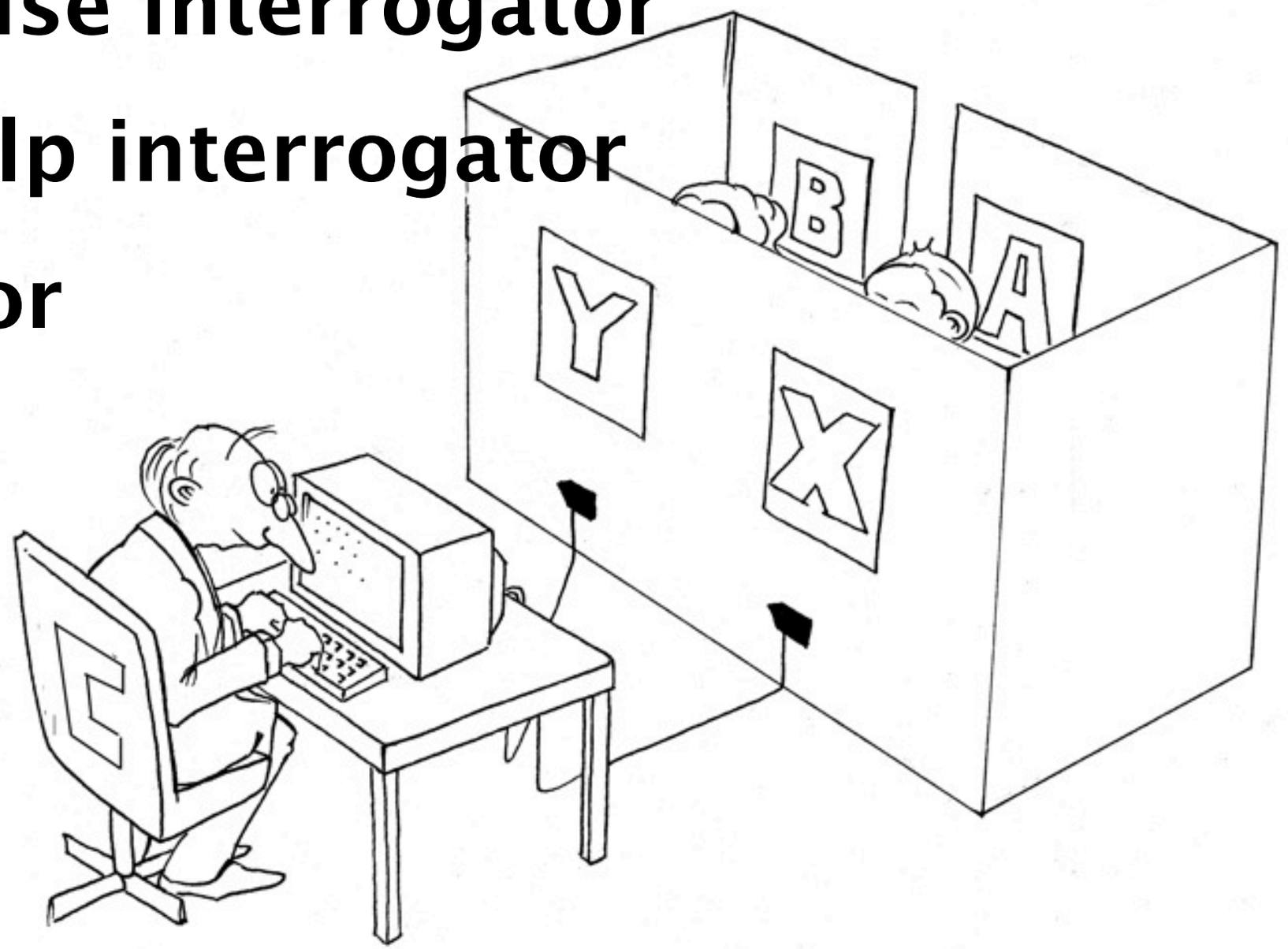
- e.g. IQ, h-index :-)
- …

The Turing Test

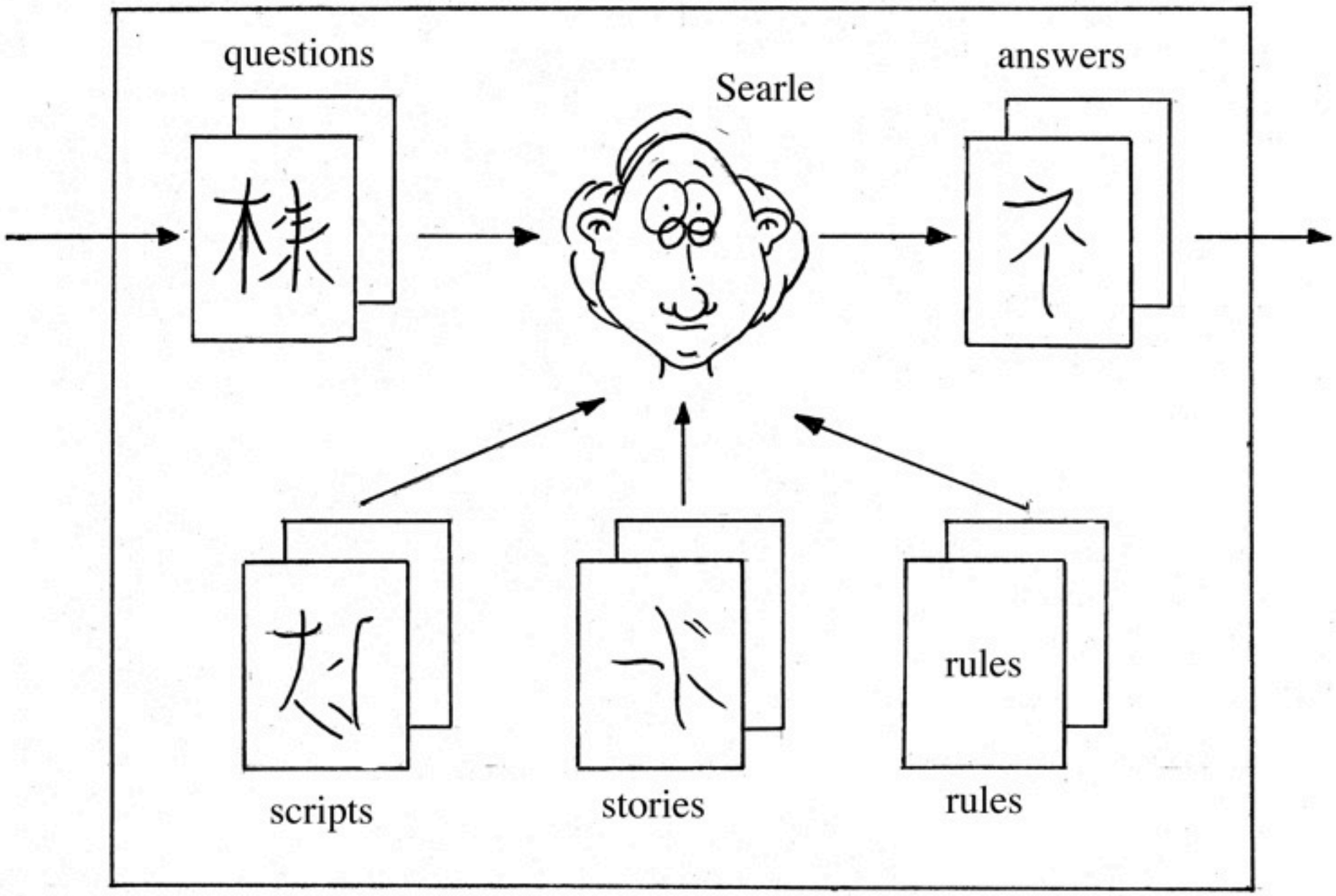
A: man, confuse interrogator

B: woman, help interrogator

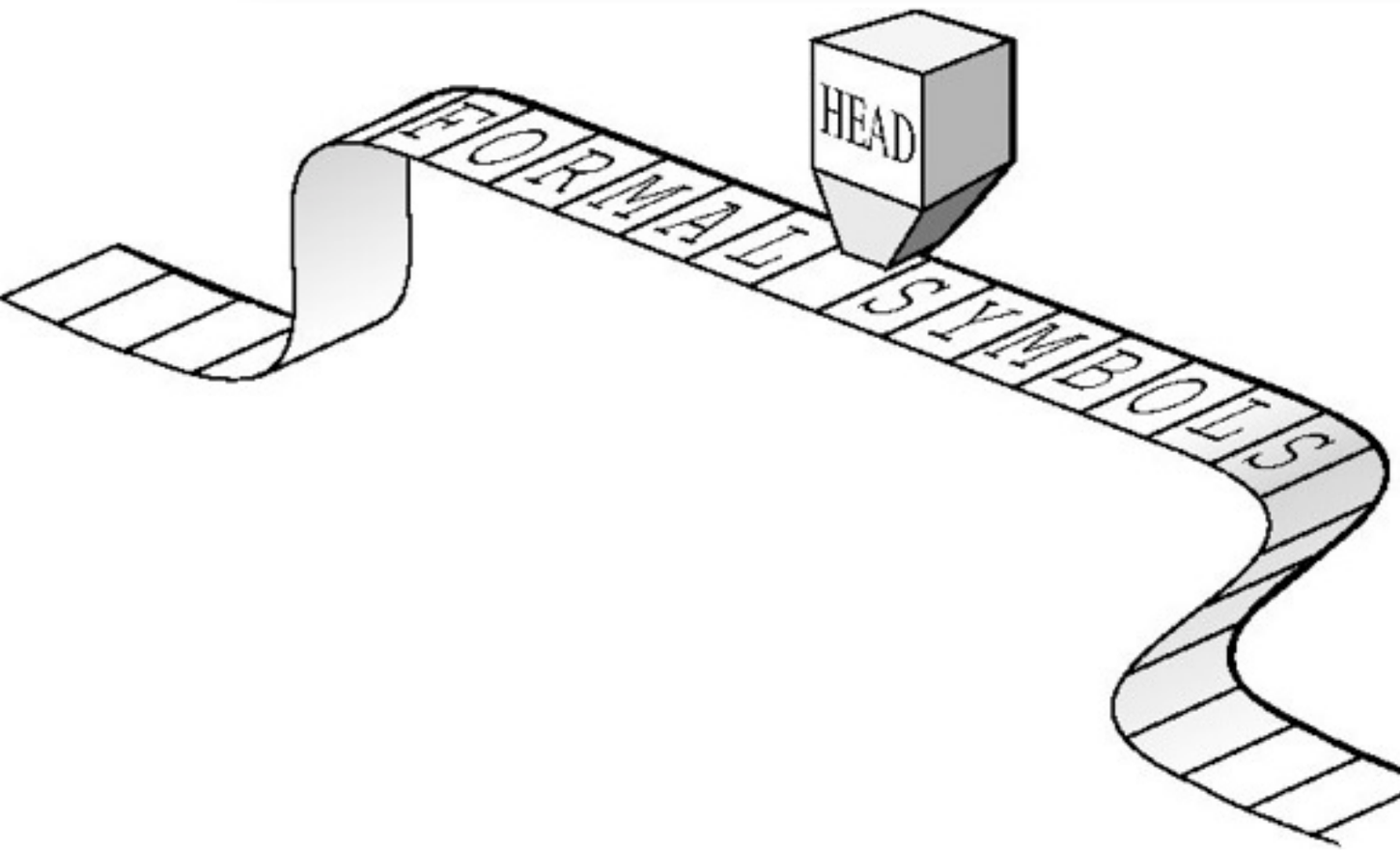
C: interrogator



Searle's "Chinese Room" thought experiment

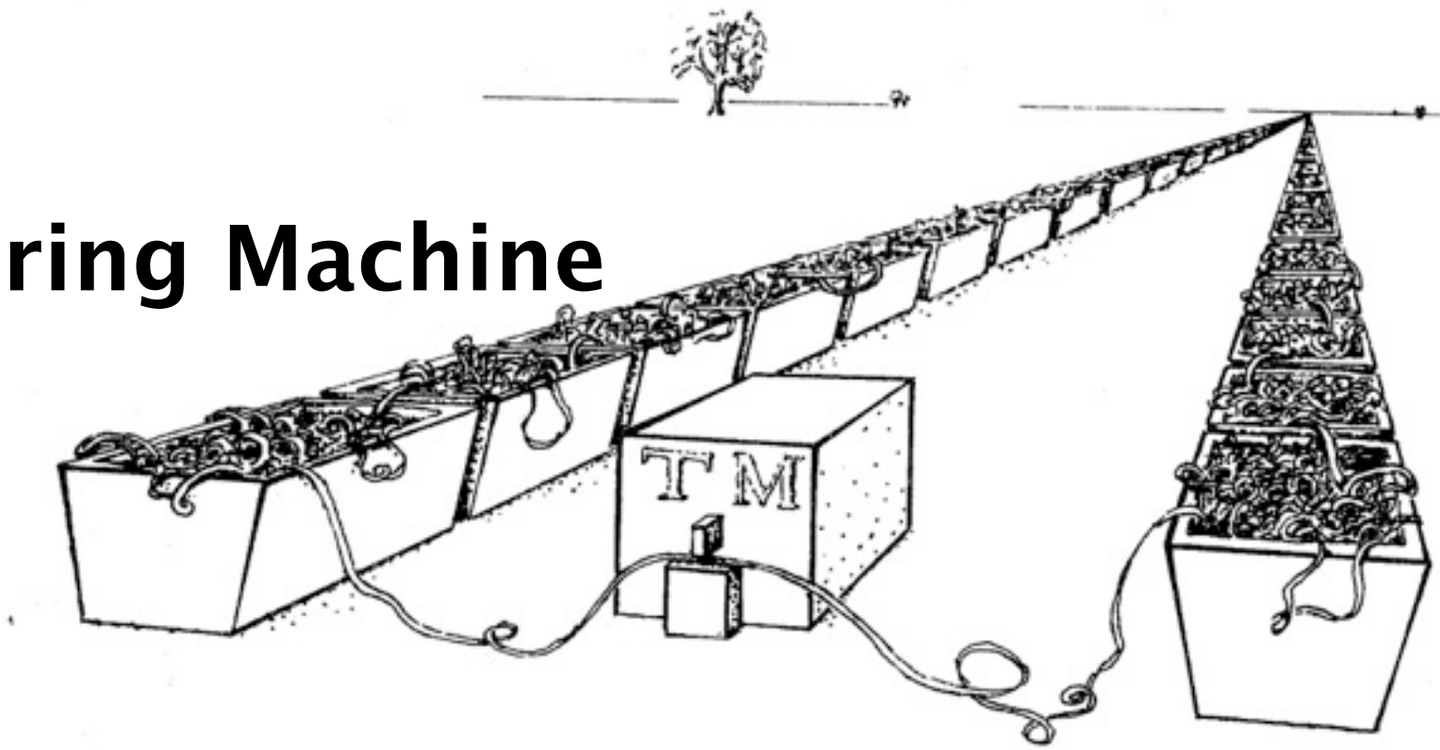


Turing Machine



Turing Machine: a problem

an “embodied” Turing Machine



Cartoon by
Roger Penrose

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**

University of Zurich[UZH]

robotics Swiss National Centre of Competence in Research

ai lab

Fundamental problems of classical approach

- “symbol grounding problem”
- “frame problem”
- “homunculus problem”

The “symbol grounding” problem

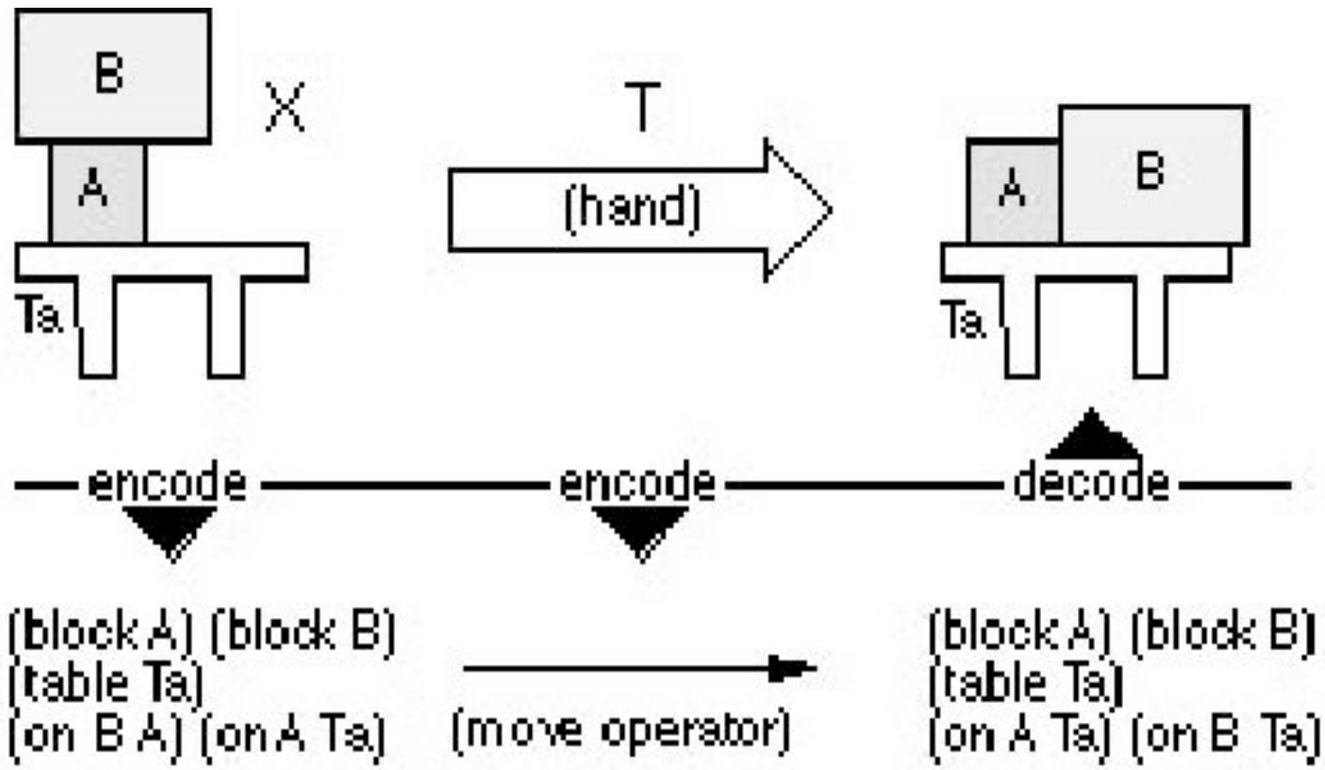
real world: doesn’t come with labels …

"Now! ... *That* should clear up a few things around here!"

Gary Larson

The “frame problem” Maintaining model of real

- **the more detailed the harder**
- **information acquisition**
- **most changes: irrelevant to current situation**



Summary of Dennett's points

- obvious to humans, not obvious to robots (robot only has symbolic model/representation of world)
- vast number of potential side effects, mostly irrelevant
- distinction between relevant an irrelevant inferences
- must test all

Two views of intelligence

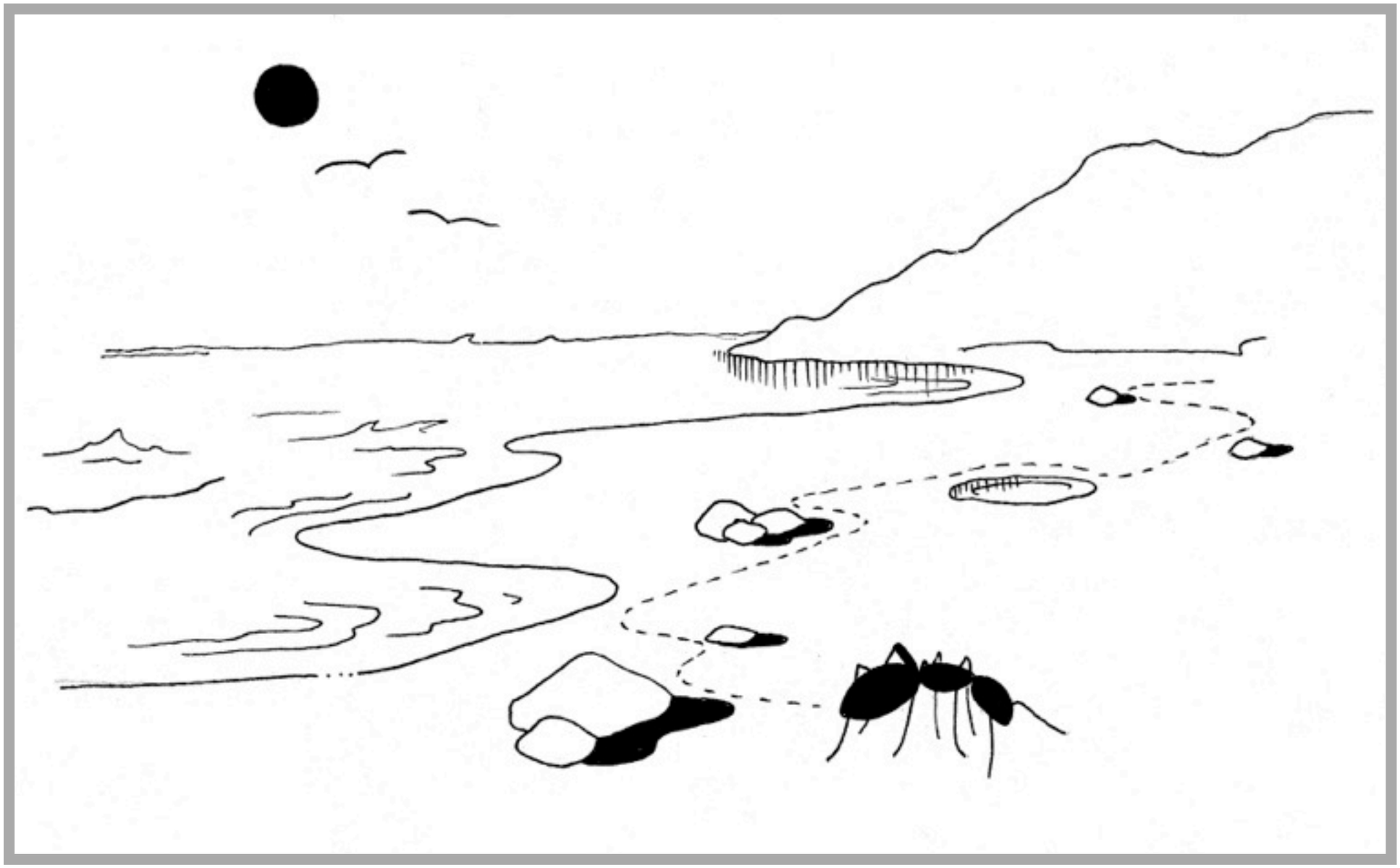
classical:
cognition as computation

embodiment:
cognition emergent from sensory-motor and interaction processes

The need for an embodied perspective

- "failures" of classical AI
- fundamental problems of classical approach
- Wolpert's quote: Why do plants not …?
- Interaction with environment: always mediated by body

“Frame-of-reference”
Simon’s ant on the beach



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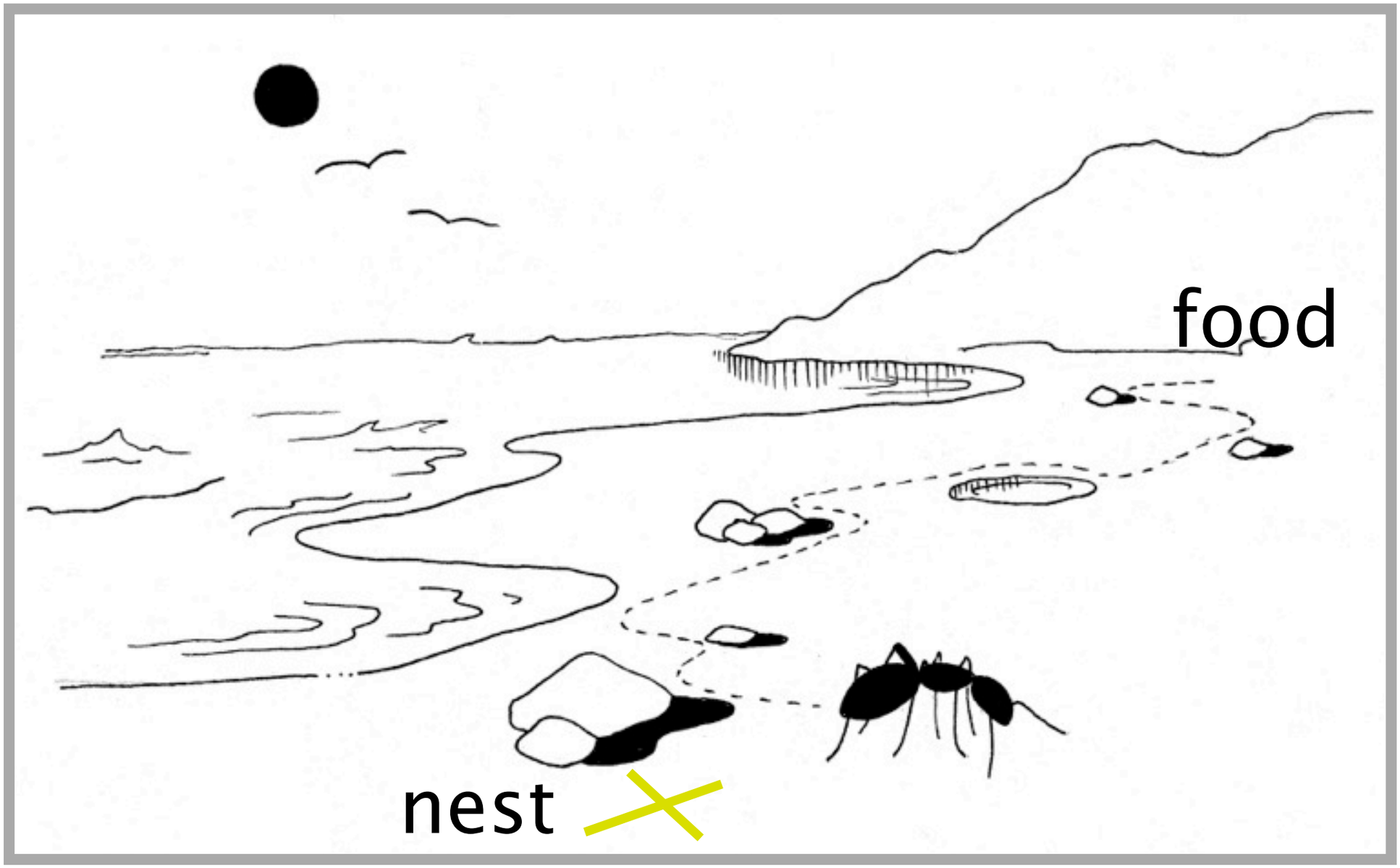
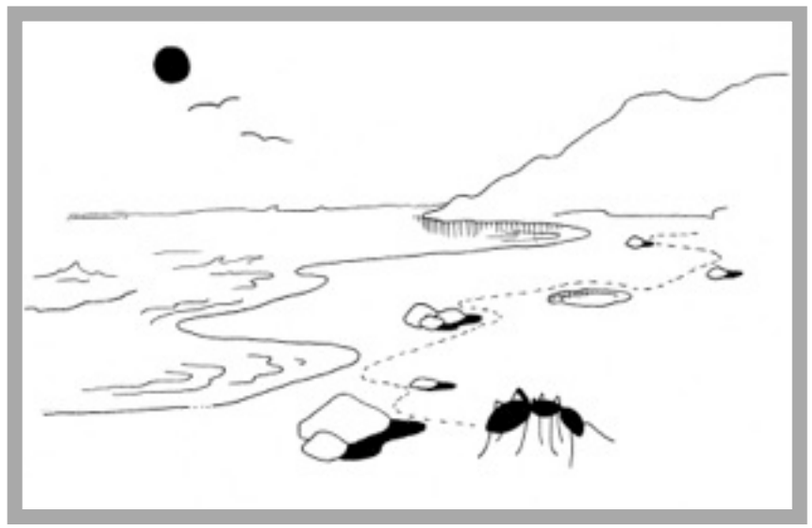


"Frame-of-reference" Simon's ant on the



- **simple behavioral rules**
- **complexity in interaction, not — necessarily — in brain**

- thought experiment: **increase body by factor of 1000**

“Frame-of-reference” F-O-R

- perspectives issue
- behavior vs. mechanism issue
- complexity issue

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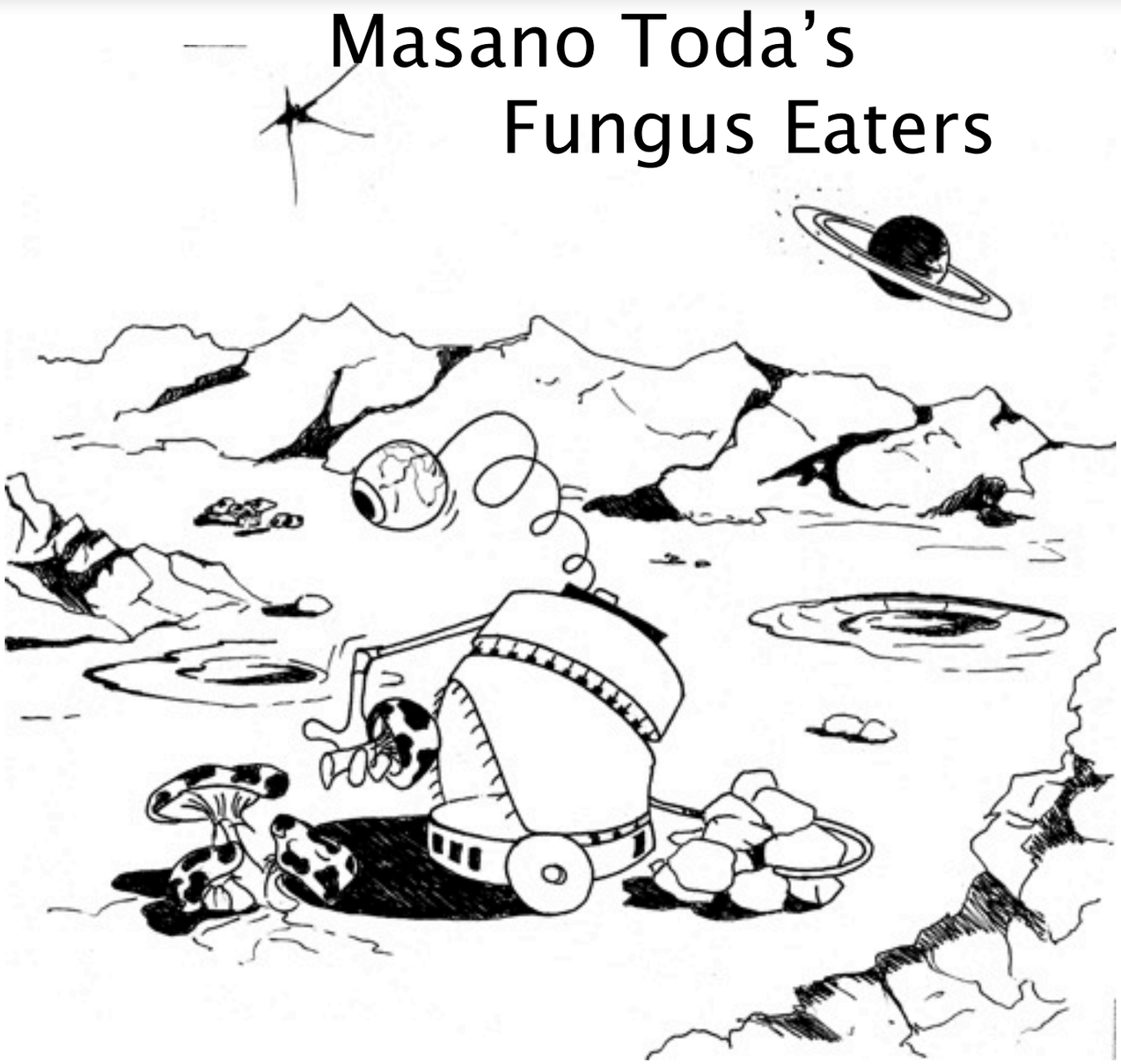
- illustration of design principles
  - parallel, loosely coupled processes: the "subsumption architecture"
  - case studies: "Puppy", biped walking
  - "cheap design" and redundancy

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

Complex dynamical systems

non-linear system – in contrast to a linear one
—> Any idea?

Complex dynamical systems

concepts: focus box 4.1, p. 93, “How the body …”

- dynamical systems, complex systems, non-linear dynamics, chaos theory
- phase space
- non-linear system — limited predictability, sensitivity to initial conditions
- trajectory

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Design principles for intelligent systems

Principle 1: Three-constituents principle

Principle 2: Complete-agent principle

Principle 3: Parallel, loosely coupled processes

Principle 4: Sensory-motor coordination/ information self-structuring

Principle 5: Cheap design

Principle 6: Redundancy

Principle 7: Ecological balance

Principle 8: Value

Three-constituents principle

define and design

- **“ecological niche”**
- **desired behaviors and tasks**
- **design of agent itself**

design stances

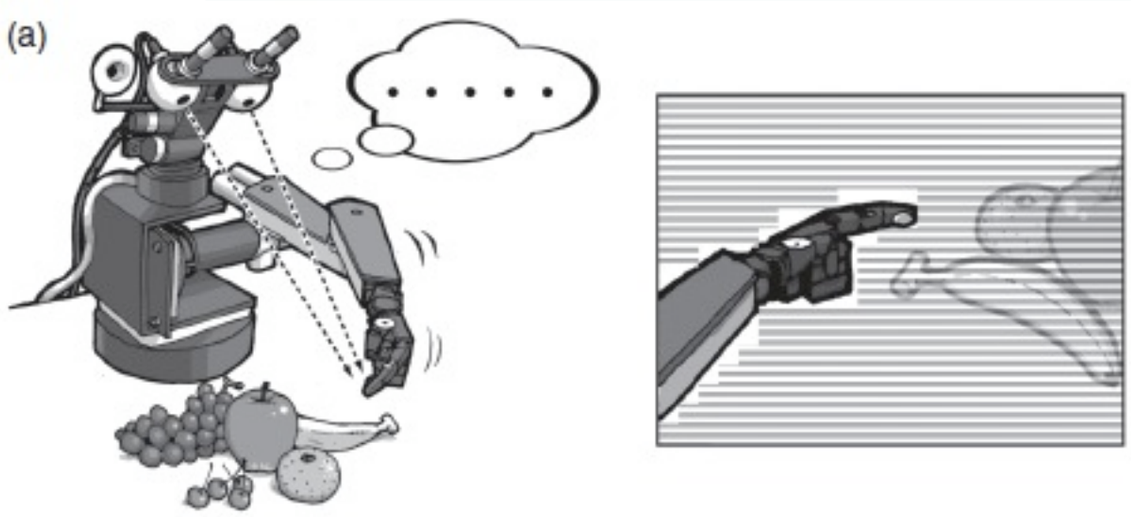
scaffolding

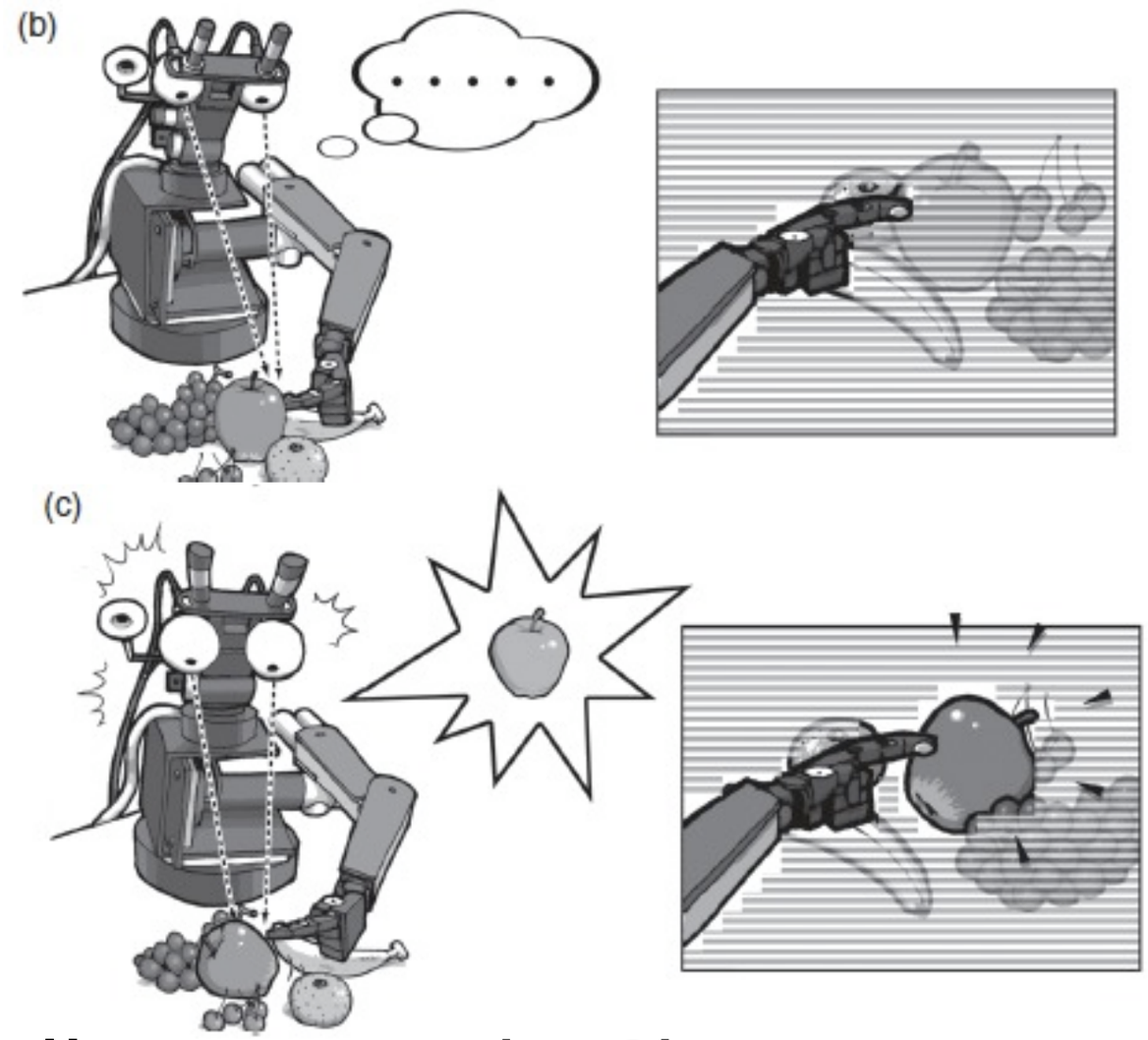
Complete-agent principle

- always think about complete agent behaving in real world
- isolated solutions: often artifacts — e.g., computer vision (contrast with active vision)
- biology/bio-inspired systems: every action has potentially effect on entire system

can be exploited!

Recognizing an object in a cluttered environment





manipulation of environment can facilitate perception

Experiments: **Giorgio Metta and Paul Fitzpatrick**

Illustrations by Shun Iwasawa

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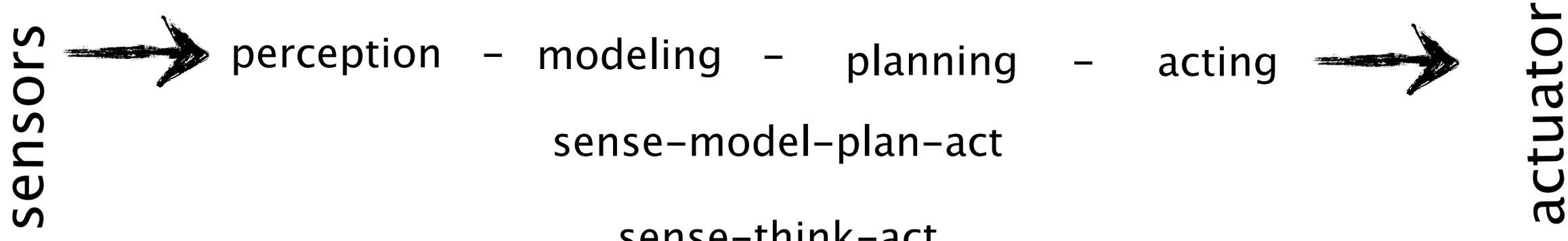
Parallel, loosely coupled processes

intelligent behavior:

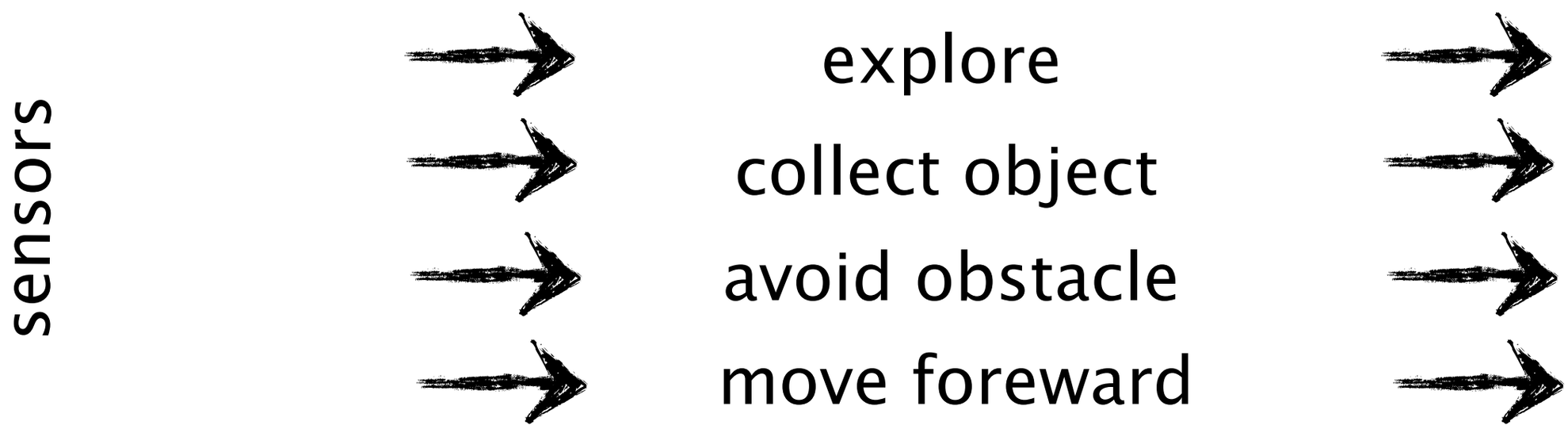
- **emergent from system-environment interaction**
- **based on large number of parallel, loosely coupled processes**
- **asynchronous**
- **coupled through agent's sensory-motor system and environment**

The subsumption architecture

classical, cognitivistic



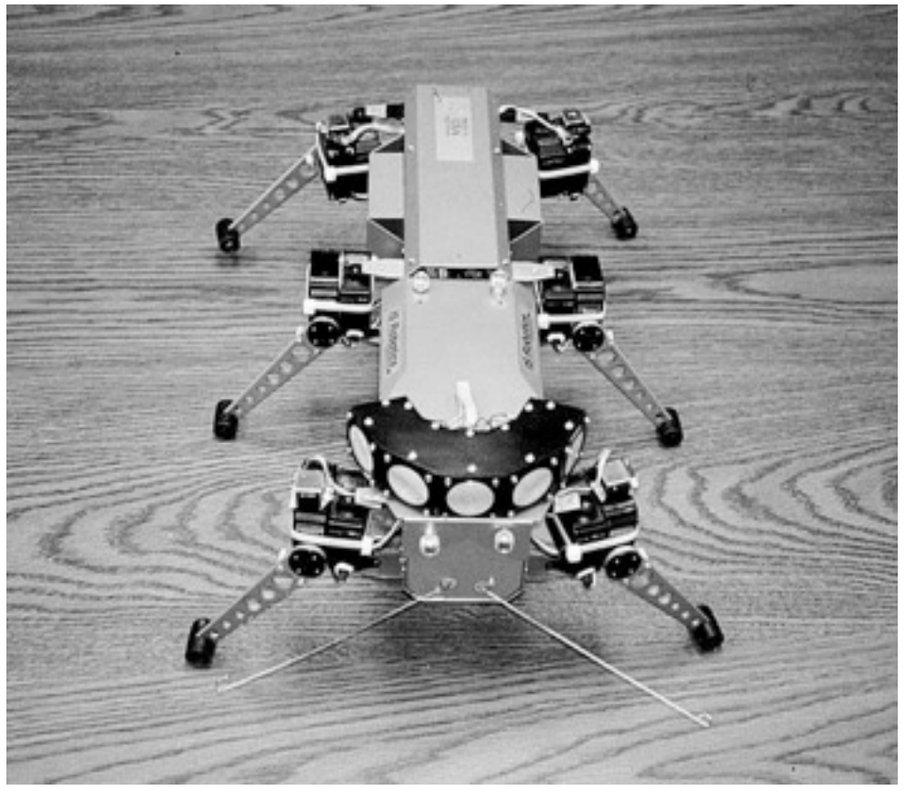
“behavior-based”, subsumption



Mimicking insect walking

- **subsumption architecture well-suited**

six-legged robot “Ghenghis”

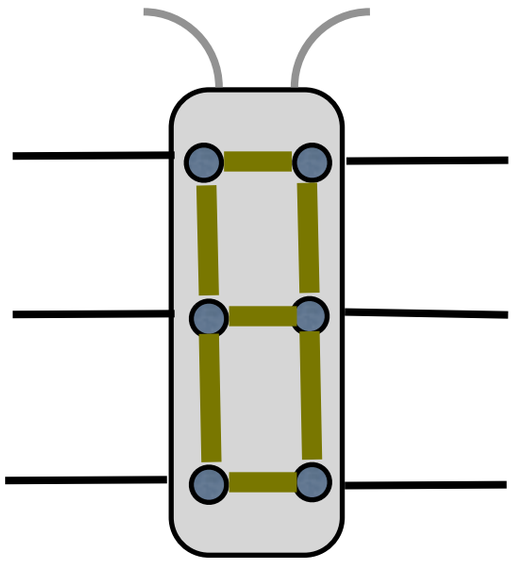


Insect walking

Holk Cruse, German biologist

- **no central control for leg coordination**
- **only communication between neighboring legs**

neural connections →

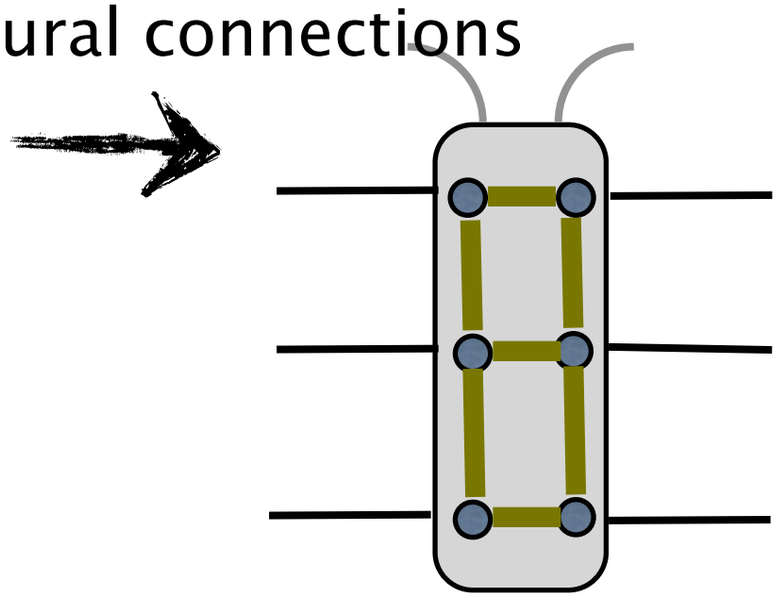


Insect walking

Holk Cruse, German biologist

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

neural connections



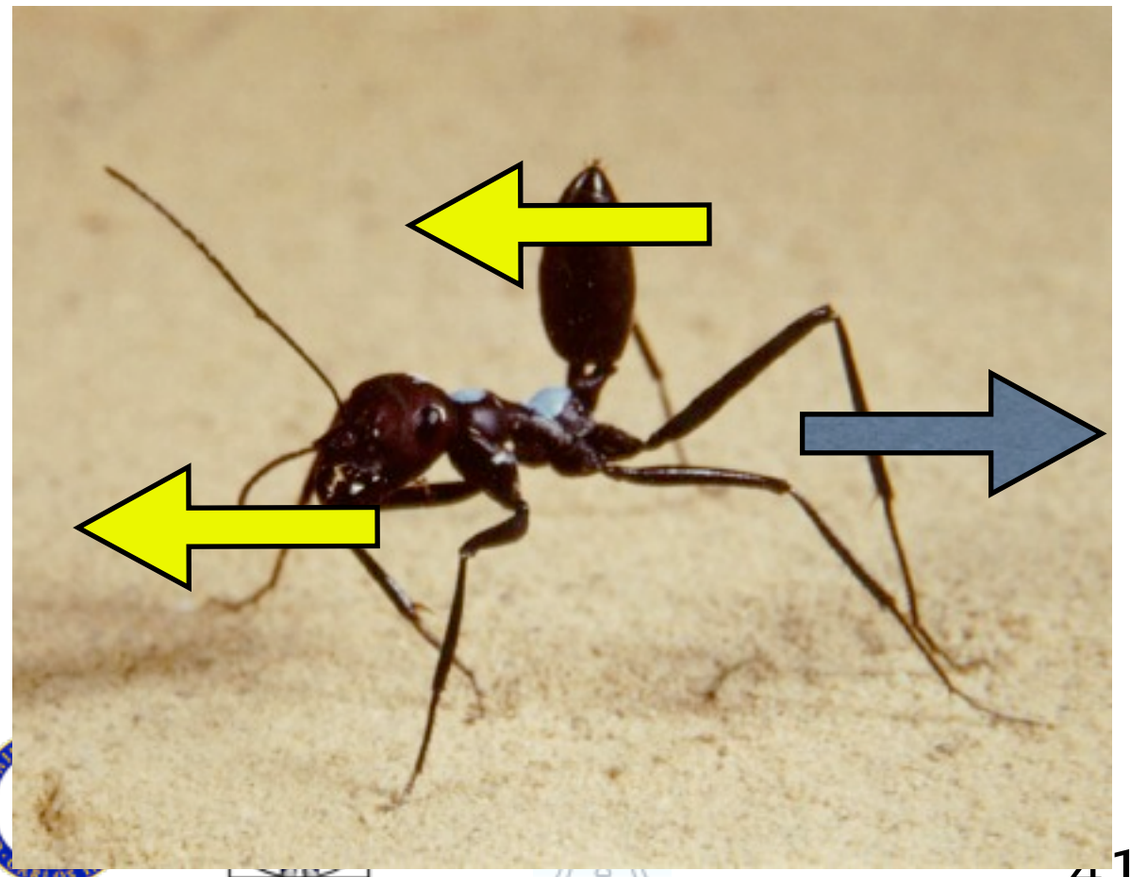
Communication through interaction with

- exploitation of interaction with environment

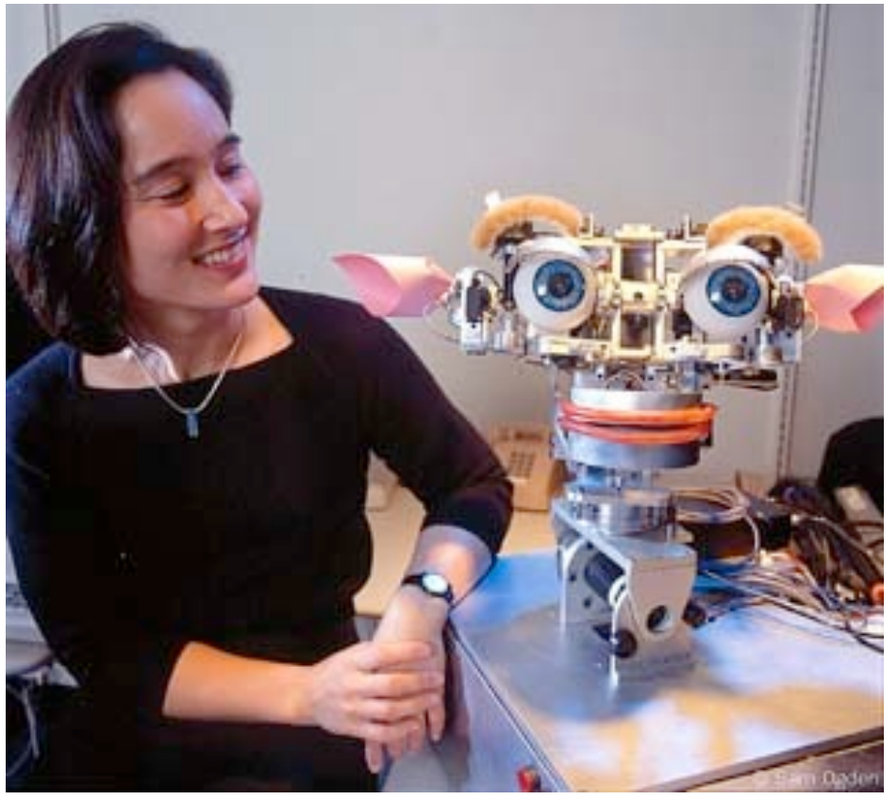
→ simpler neural circuits

angle sensors in joints

"parallel, loosely coupled processes"



Kismet: The social interaction robot



Cynthia Breazeal, MIT Media Lab
(prev. MIT AI Lab)

Kismet: The social interaction robot

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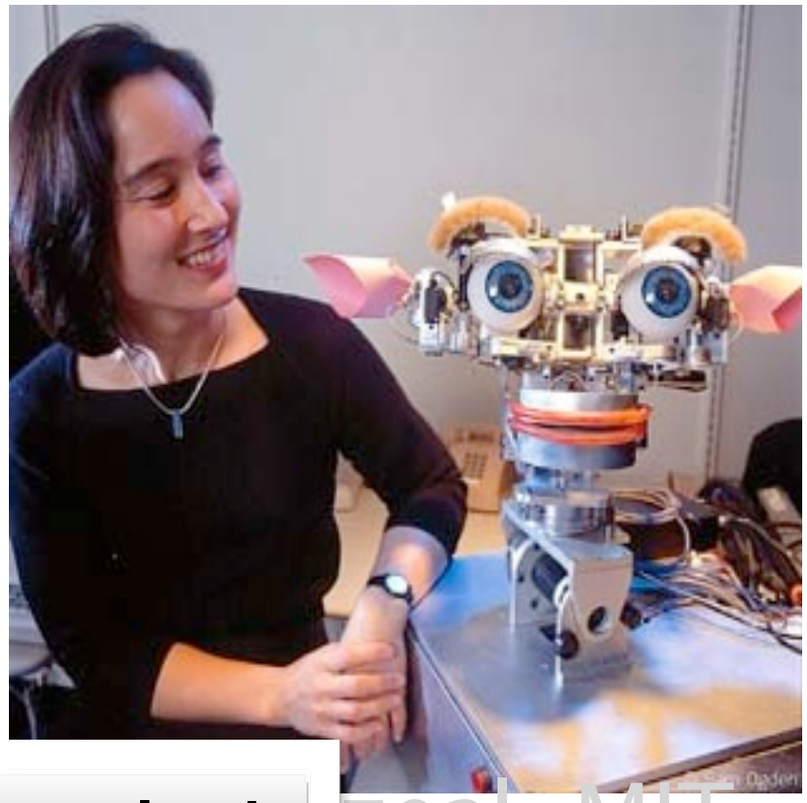
Kismet: The social interaction robot

Reflexes:

- **turn towards loud noise**
- **turn towards moving objects**
- **follow slowly moving objects**
- **habituation**



principle of “parallel, loosely coupled processes”

zeal, MIT

lab (prev. MIT AI Lab)

Kismet: The social interaction robot

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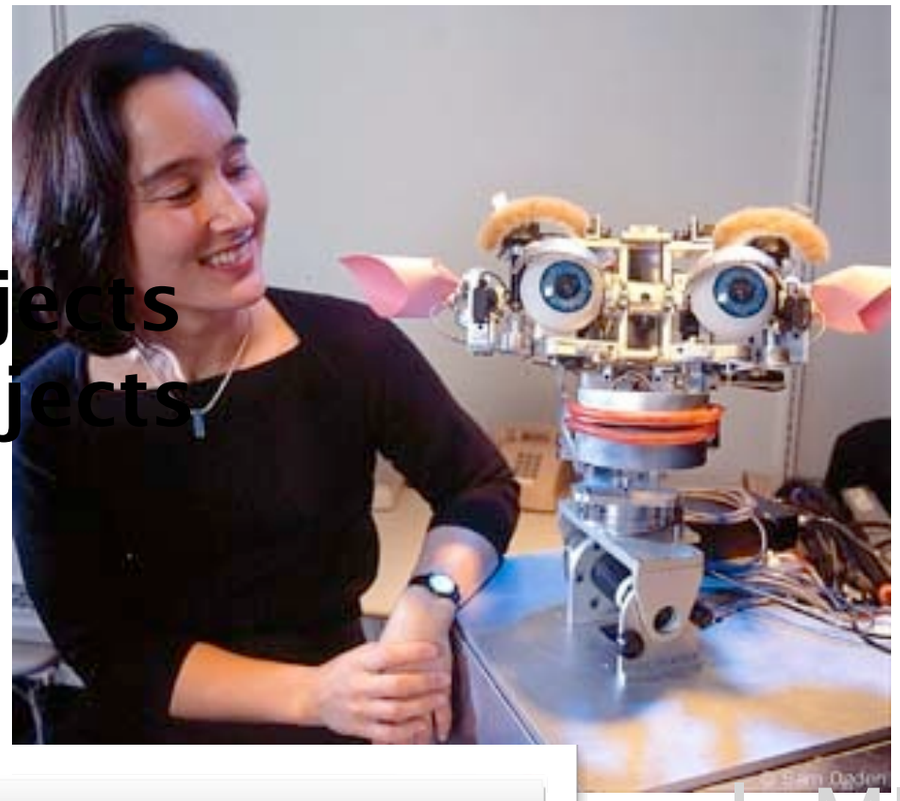

social competence: a collection of reflexes ?!?!???

zeal, MIT

lab (prev. MIT AI Lab)

Scaling issue: the "Brooks-Kirsh"

insect level —> human level?

David Kirsh (1991): "Today the earwig, tomorrow man?"

Rodney Brooks (1997): "From earwigs to humans."

Scaling issue: the "Brooks-Kirsh"

insect level —> human level?

David Kirsh (1991): "Today the earwig, tomorr

Rodney gs to human

volunteer for brief presentation on the "Brooks-Kirsh" debate – or generally, scalability of subsumption (on a later date)

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- **case studies: "Puppy", biped walking**
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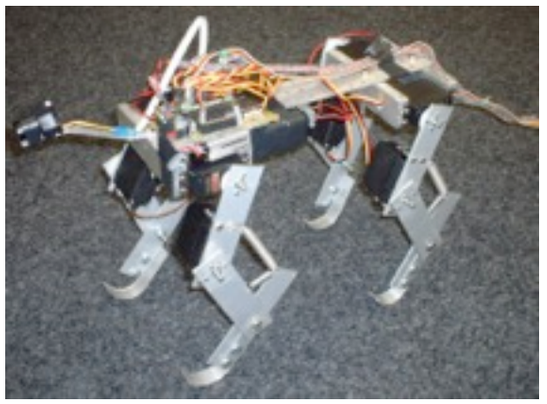
Case study: “Puppy” as a complex dynamical

- **running: hard problem**
- **time scales: neural system — damped oscillation of knee-joint**
- **“outsourcing/offloading” of functionality to morphological/material properties**

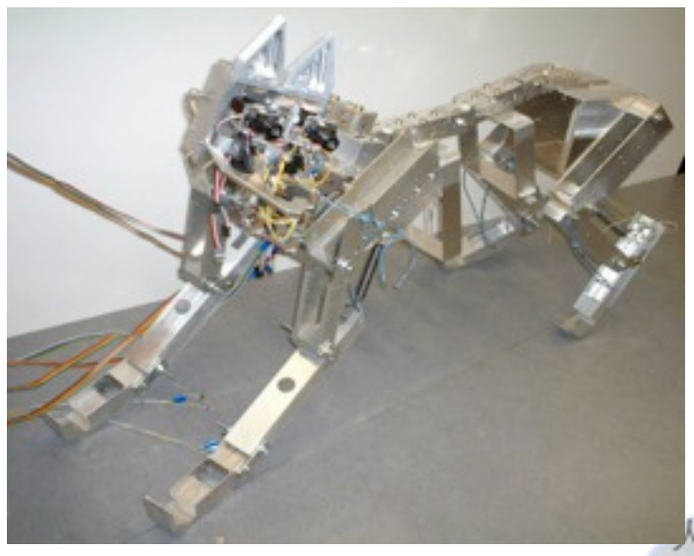
morphological computation

Recall: "Puppy's" simple control

rapid locomotion in biological systems



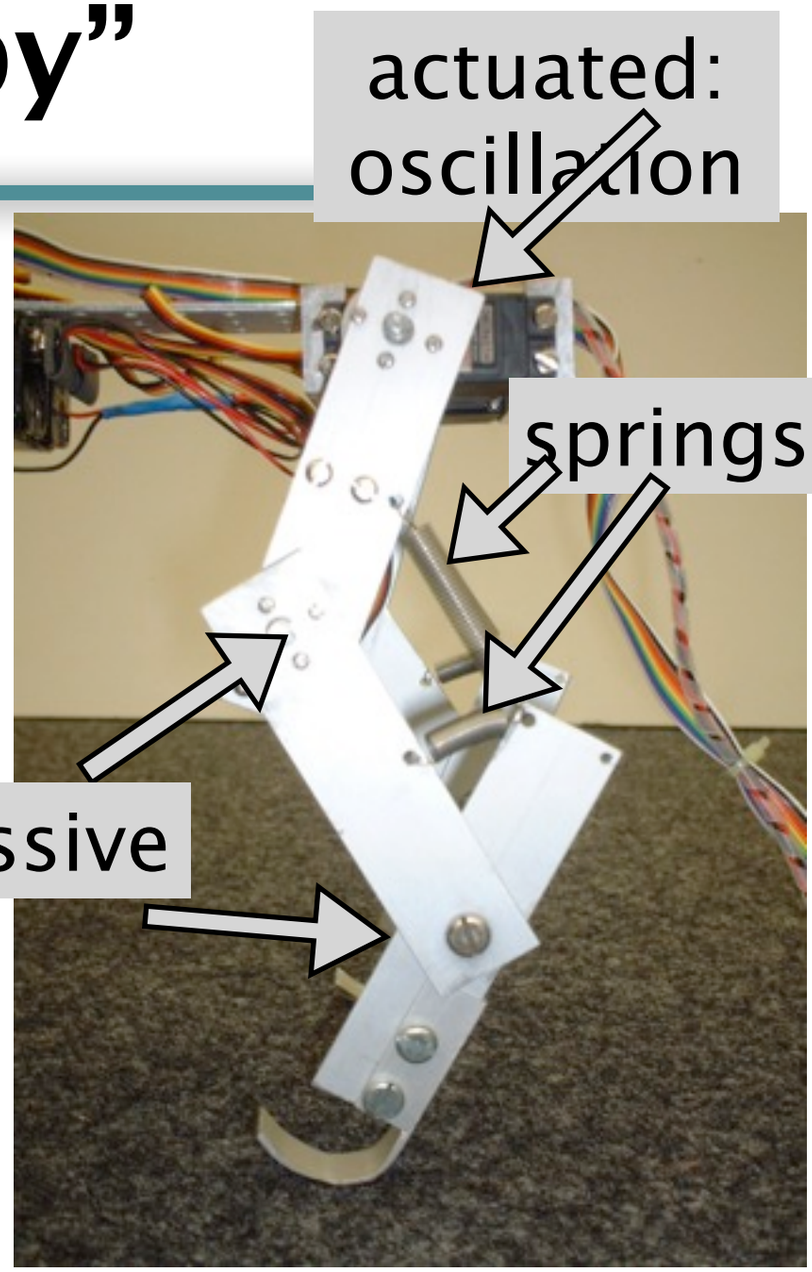
recall: emergence of behavior



Design and construction:
Fumiya Iida, AI Lab, UZH and ETH-Z

Emergence of behavior: the quadruped “Puppy”

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



→ morphological computation

Self-stabilization: “Puppy” on a treadmill

Video “Puppy” on treadmill

Self-stabilization: “Puppy” on a treadmill

Video “Puppy” on treadmill slow motion

- **no sensors**
- **no control**

→ self-stabilization

Self-stabilization: “Puppy” on a treadmill

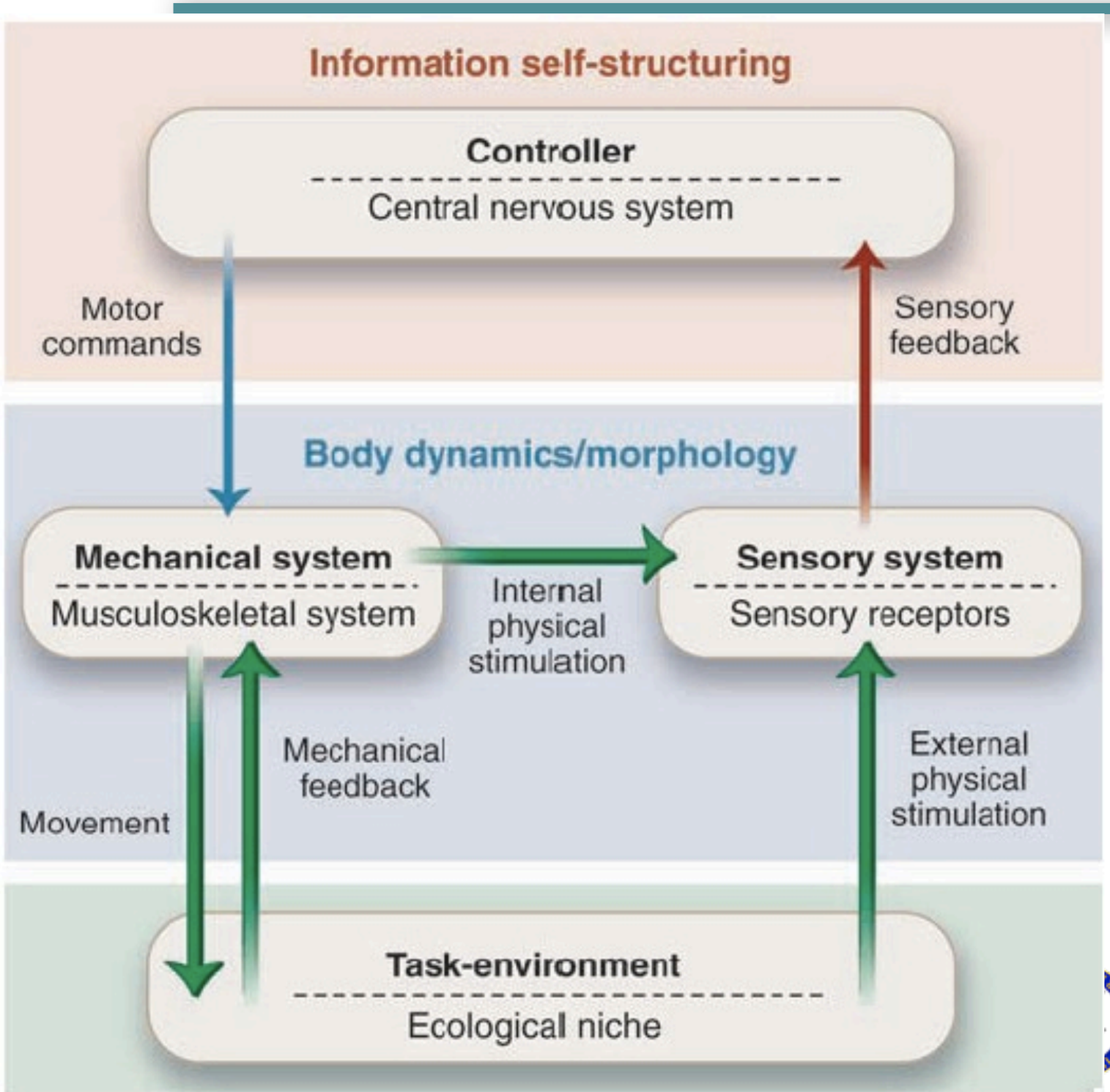
Video “Puppy” on treadmill slow motion

- **no sensors**
- **no control**

principle of “cheap design”

self-stabilization

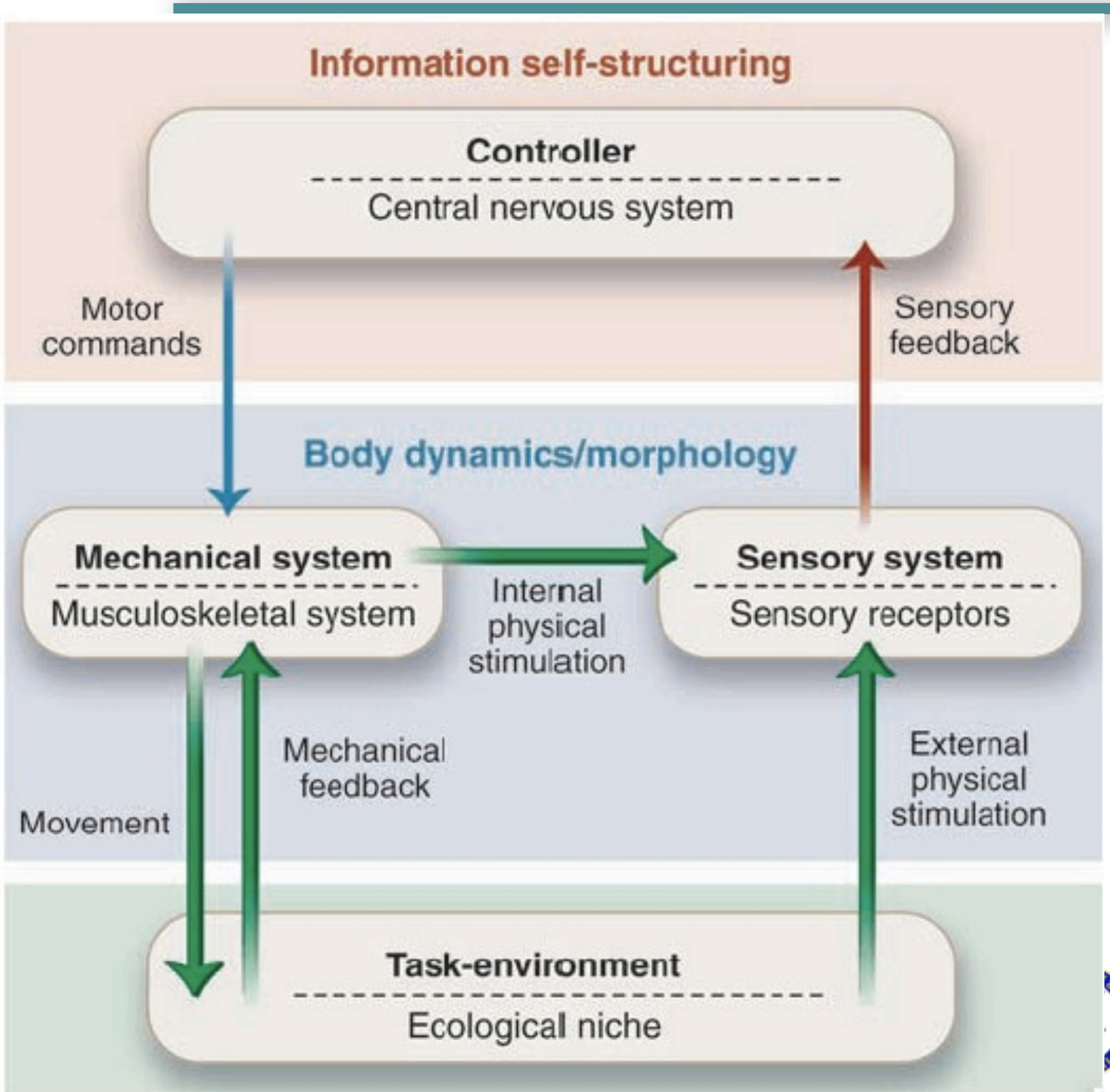
Implications of embodiment



"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

Next lecture: From locomotion to cognition

- Check chapters 4 and 5 in "How the body …"

End of lecture 7

Thank you for your attention!

stay tuned for lecture 8

“From locomotion to cognition”