
人工
智能
The
ShanghAI
Lectures
上海
授课

Lecture 3
Embodiment: Concept and Models

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The BioRobotics Institute, SSSA, Pisa, Italy and Heron Robots

Today's topics

- short recap
- The classical approach: Cognition as computation
- Successes and failures of the classical approach
- Some problems of the classical approach
- The need for an embodied approach

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“Birth” of AI, 1956

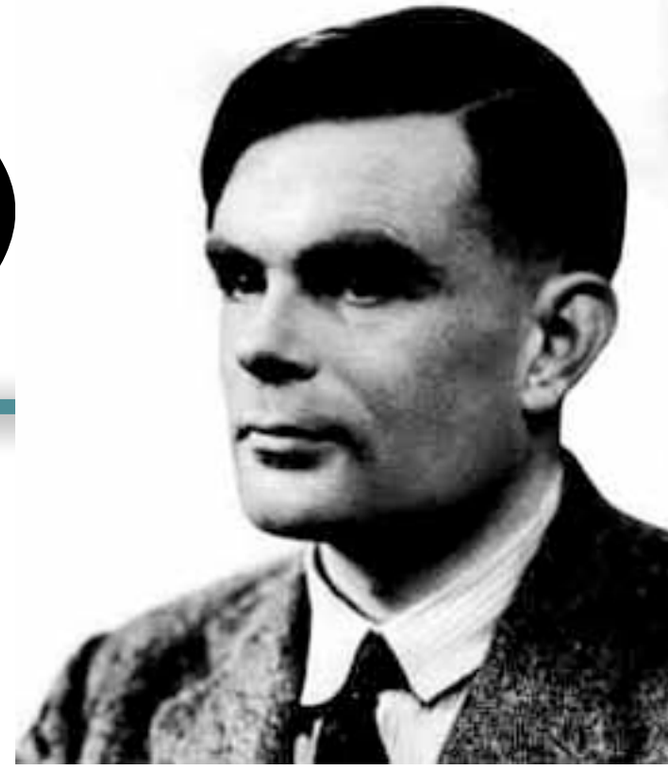
Herbert Simon
and Allen Newell
The “Logic Theorist”

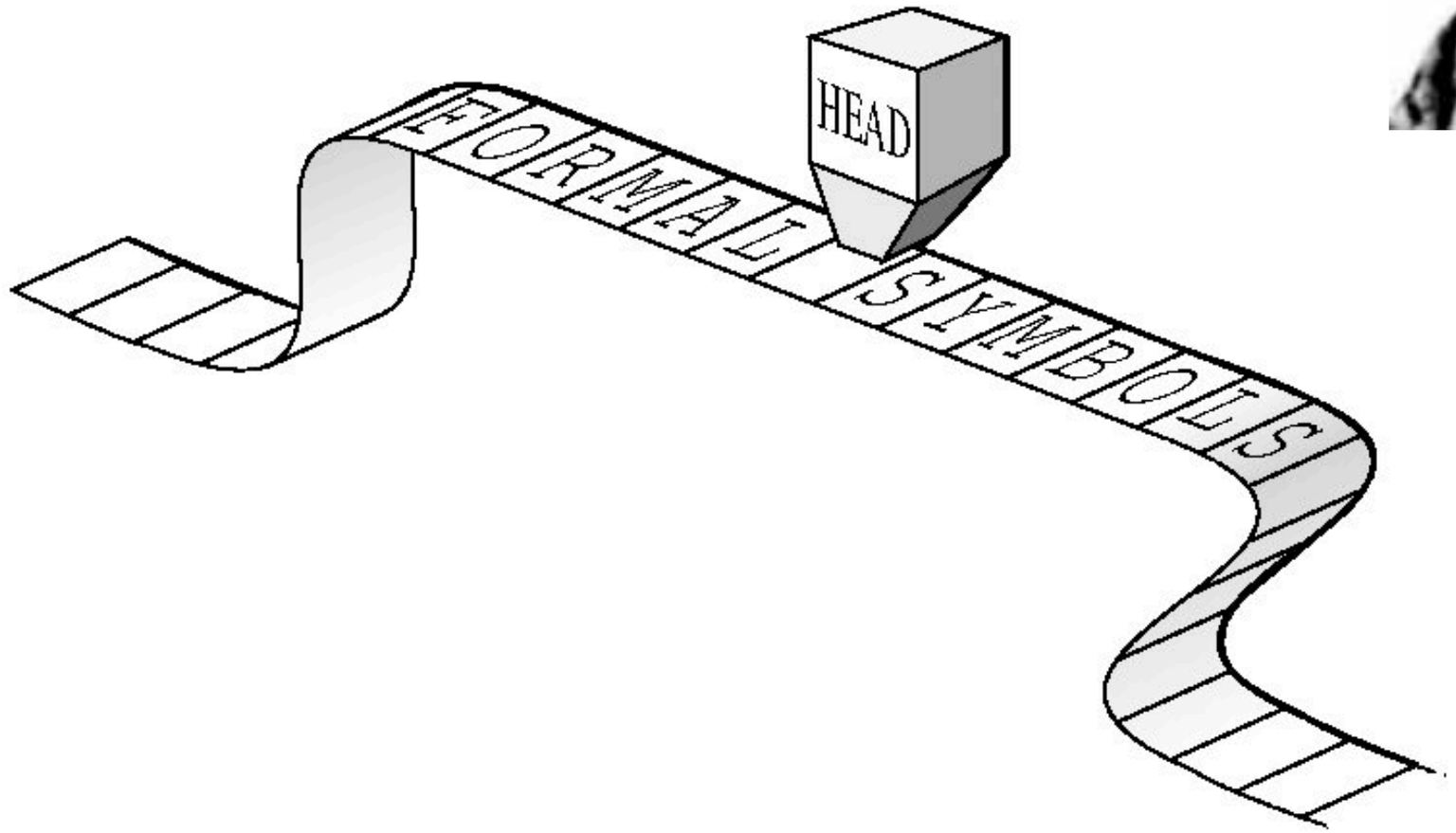
George A. Miller, Psycho
“The Magical Number Seven Plus or Minus Two”

John McCarthy, Computer Scientist
Initiator of Artificial Intelligence

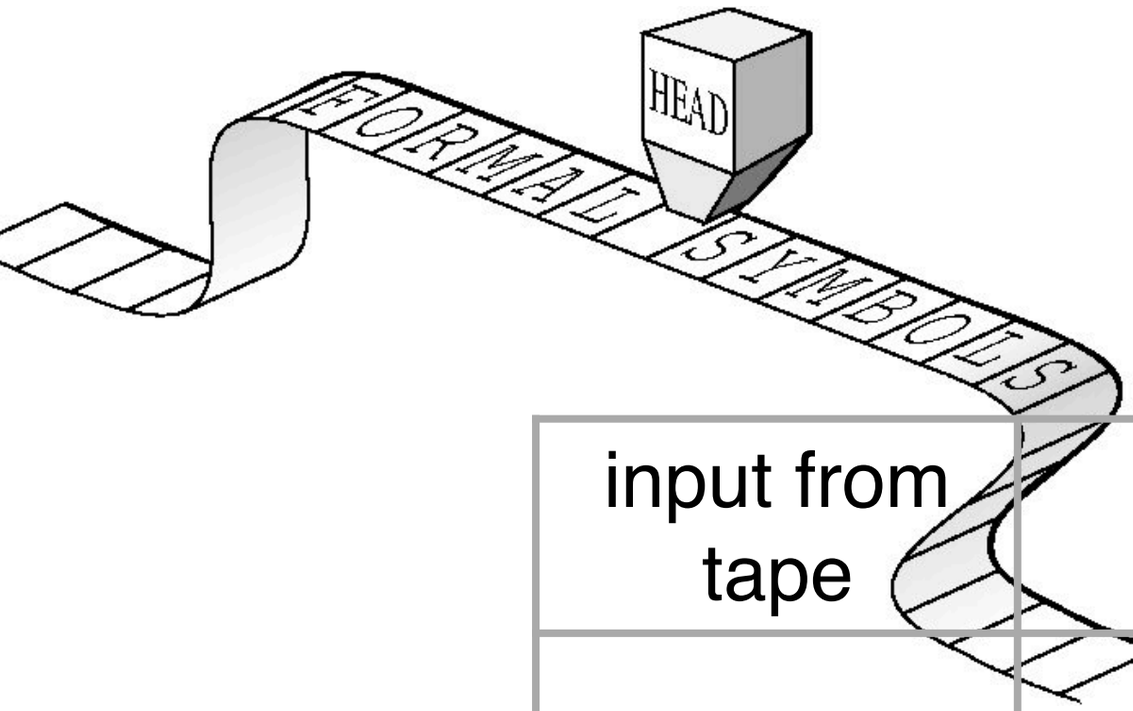
Noam Chomsky,
Linguist
“Syntactic Structures”

Turing Machine (1)





Turing Machine (2)



input from tape	1	2	← state of read/write
_	_R2	HALT	
A	AL1	BR2	
B	BL1	AR2	
C	CL1	CR2	

write on tape move tape L/R

next state of r/w head

initial situation: state r/w head = 1

initial content of tape:

. . . A A B A A C C C C A B A C C C C B B A B . . .

r/w head initial pos.

input from tape	1	2	← state of read/write
_	_R2	HALT	
A	AL1	BR2	
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write on tape move tape L/R next state of r/w head

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initial content of tape:

r/w head initial pos.

Turing Machine (4)

input from tape	1	2	← state of read/write
_	_R2	HALT	
A	AL1	BR2	
B	BL1	AR2	
C	CL1	CR2	

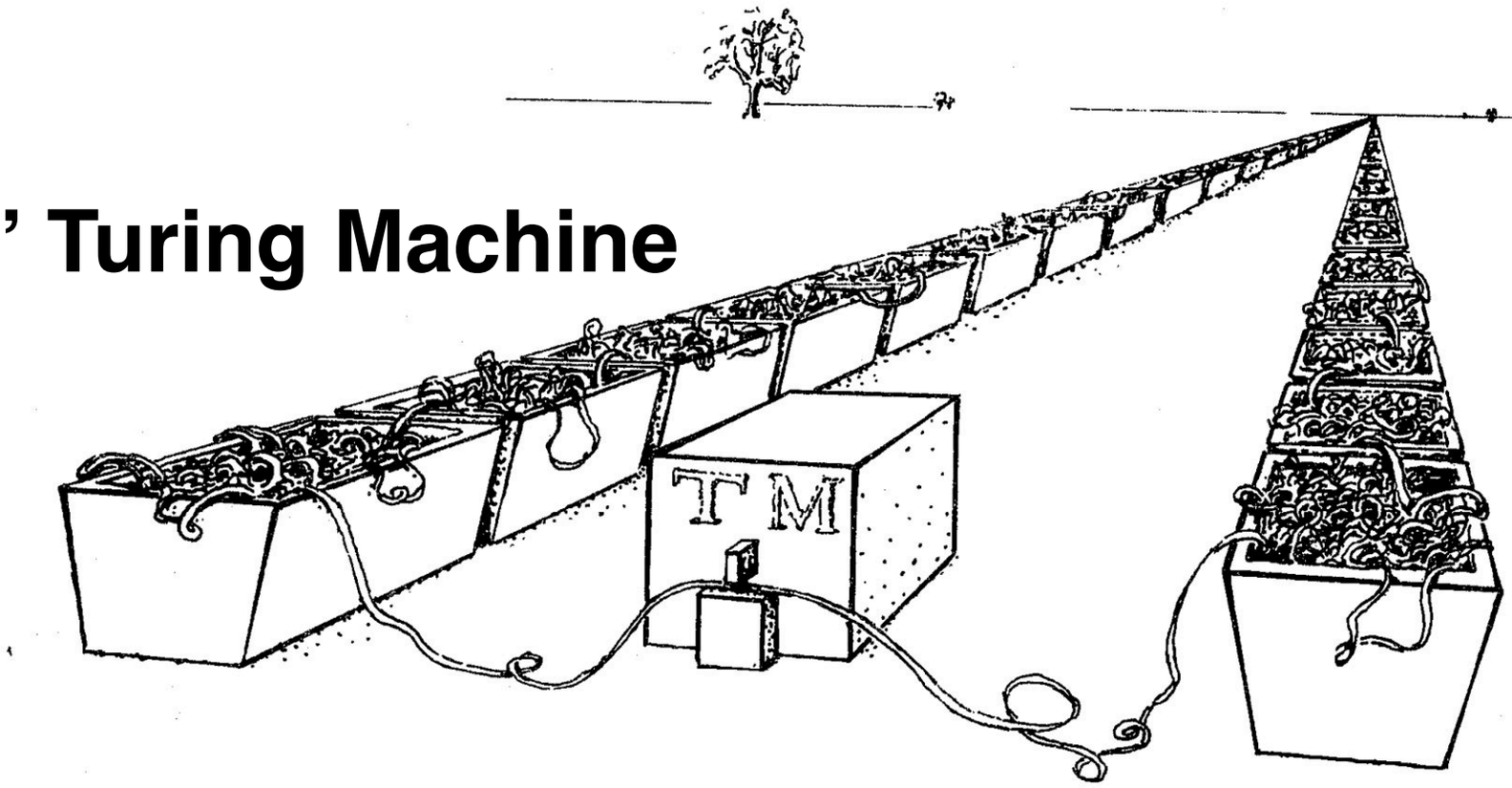
write on tape move tape L/R

next state of r/w head

The Universal Turing Machine

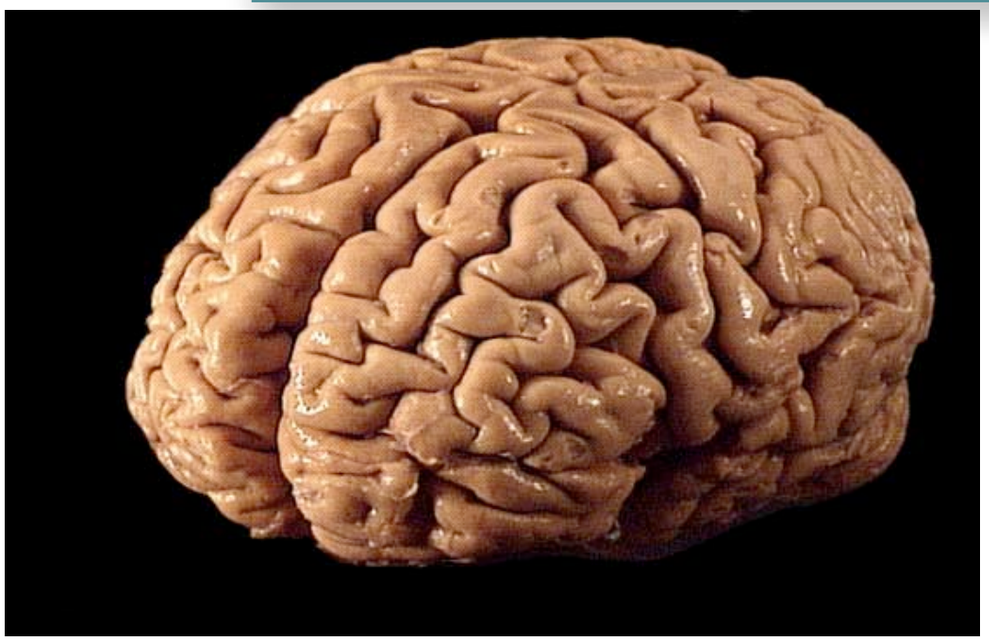
Turing Machine (5)

an “embodied” Turing Machine



Cartoon by
Roger Penrose

Functionalism and the "Physical Symbol Systems

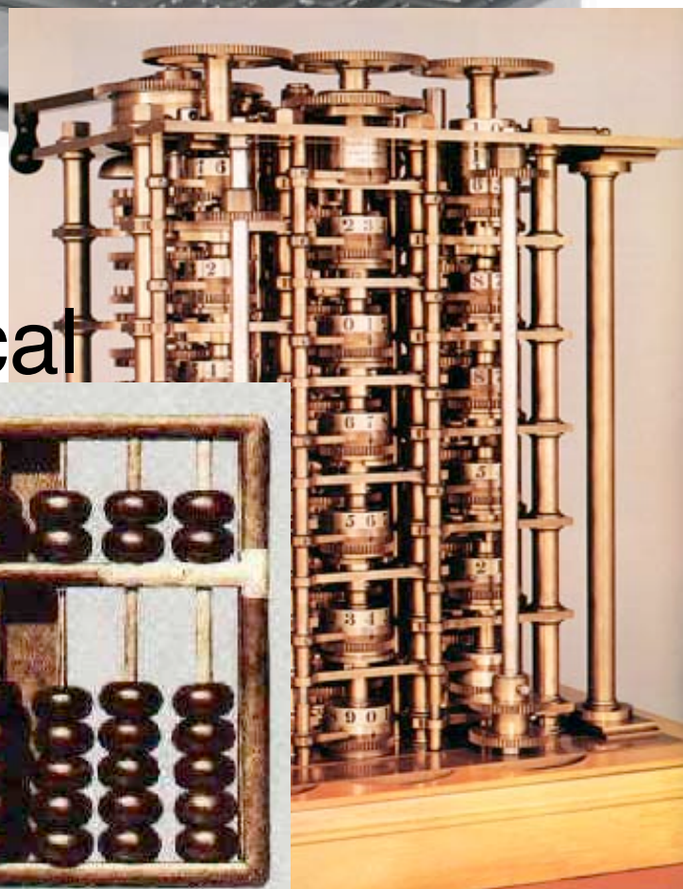


biological

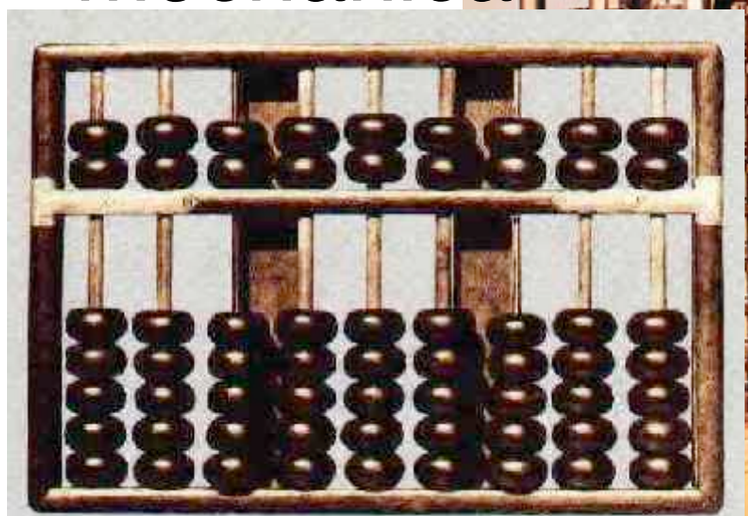
electronic

Swiss cheese

Hilary Putnam (American Philosopher)

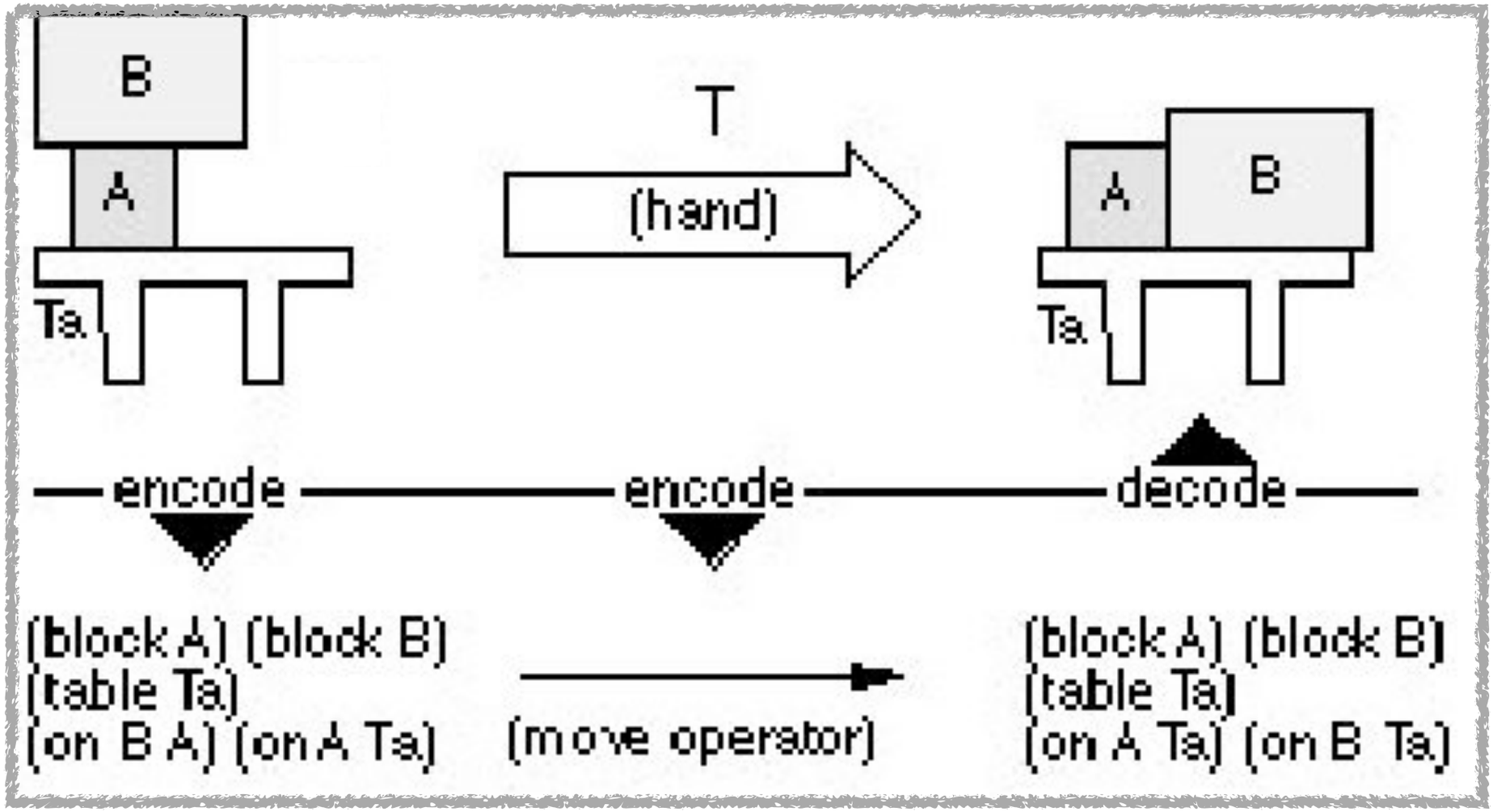


mechanical



Functionalism and the "Physical Symbol Systems

Model/Representation:



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Classical AI: Research areas

- problem solving
- knowledge representation and reasoning
- acting logically
- uncertain knowledge and reasoning
- learning and memory
- communicating, perceiving and acting
- (adapted from Russell/Norvig: Artificial intelligence, a modern approach)

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Classical AI: Successes

- search engines
- formal games (chess!)
- text processing systems/translation —> next week
- data mining systems
- restricted natural lan
- appliances

Indistinguishable from computer applications in general

Chess: New York, 1997

1 win 3 draws 2 wins

Classical AI: Failures

- recognizing a face in the crowd
- vision/perception in the real world
- common sense
- movement, manipulation of objects
- walking, running, swimming, flying
- speech (everyd

in general:
more natural forms of intelligence

Why is perception hard?

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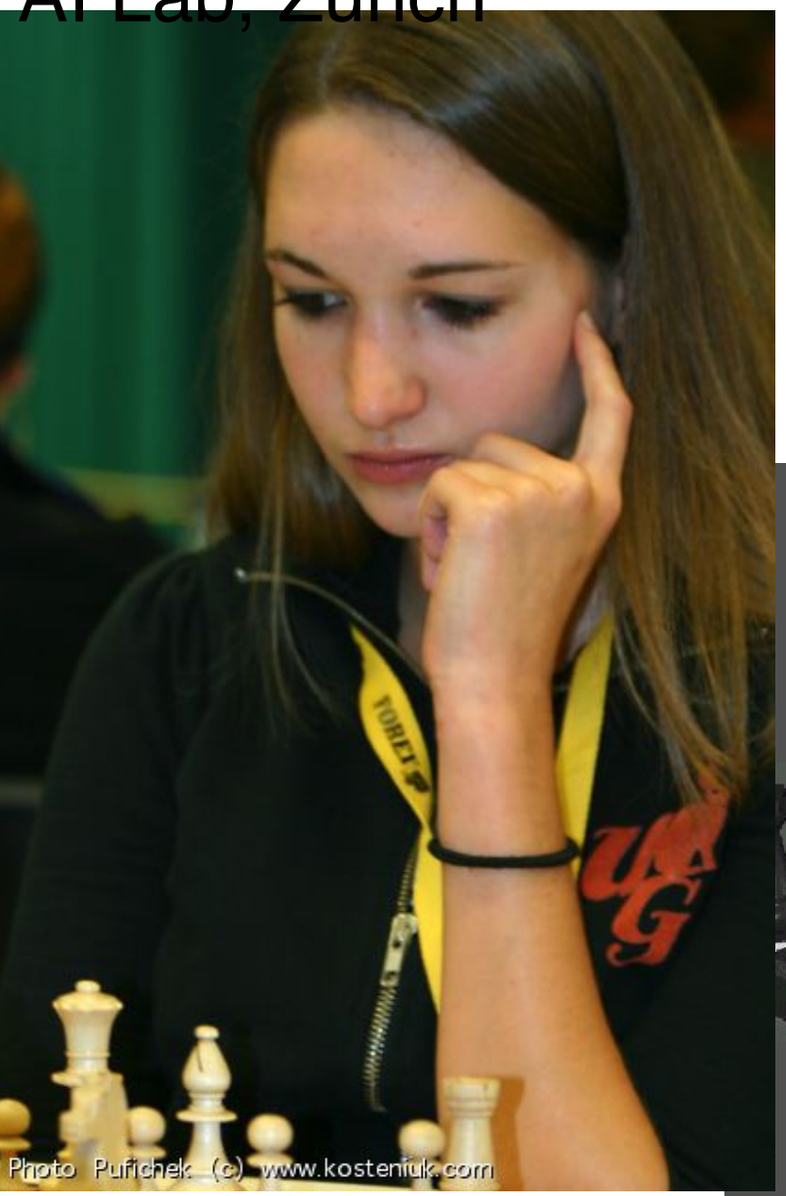
Fundamental problems of the classical approach

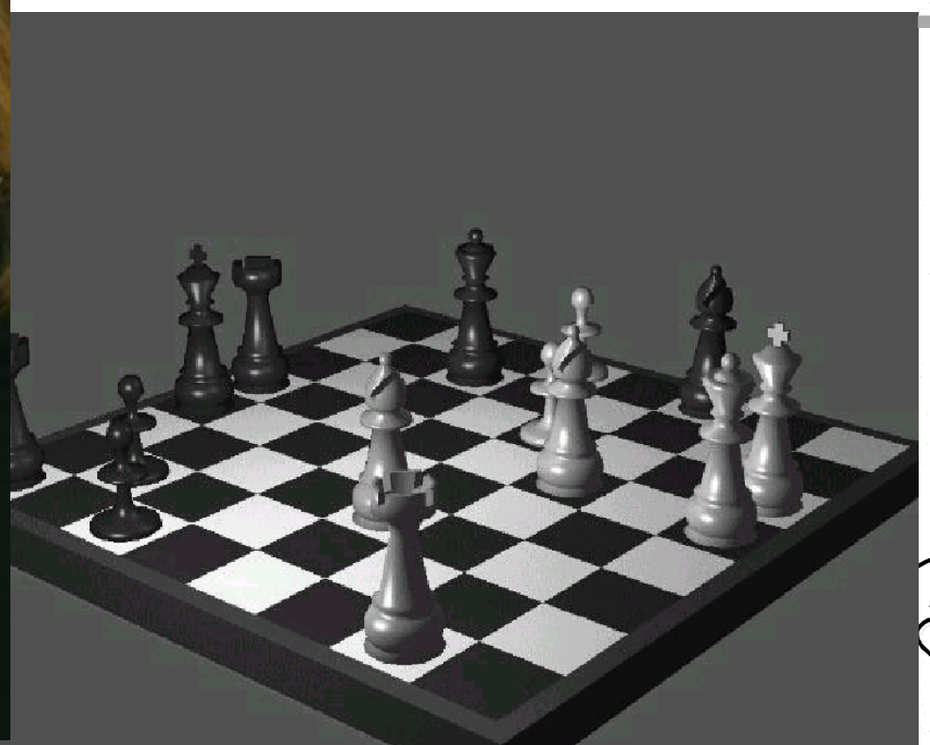
Monika Seps, chess maste
former master student
AI Lab, Zurich



in general:
anything to do with real world interaction

fundamental differences: real — virtual

virtual, formal world



real world

Fundamental problems of the classical approach

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anything to do with real world interaction

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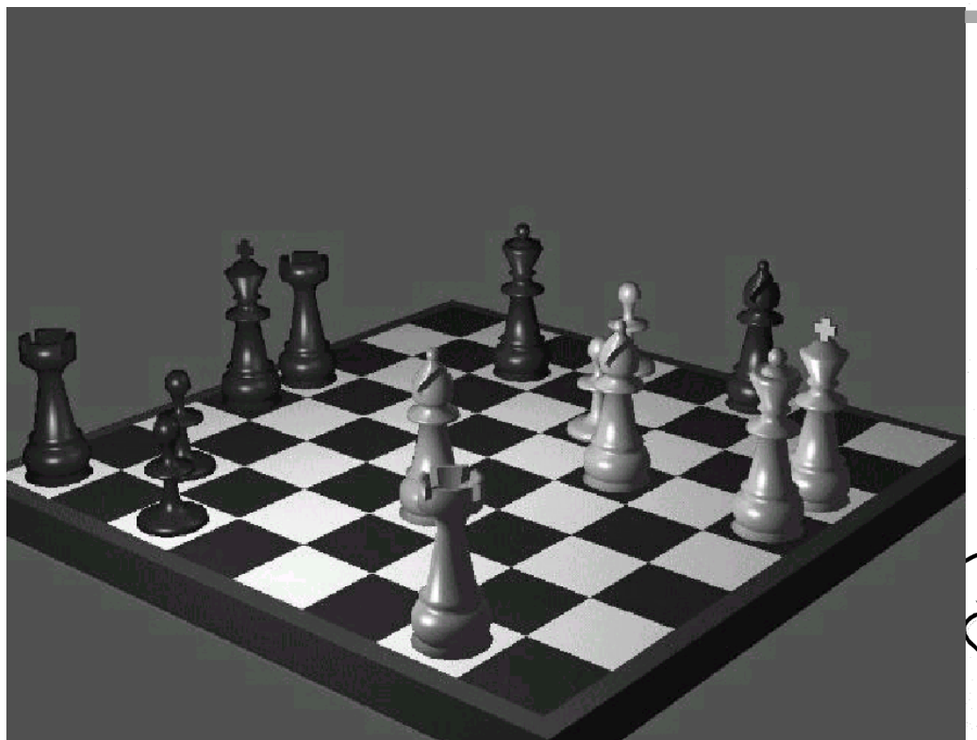


real world

Differences
real vs. virtual worlds

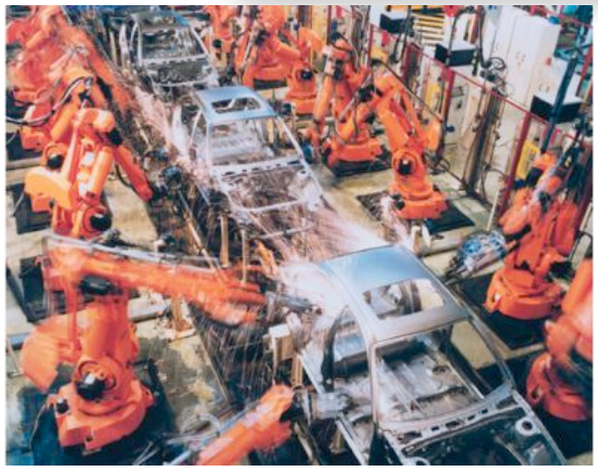
Successes and failures of the classical approach

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

Industrial environments vs.

industrial environments	real world environment
environment well-known	**limited knowledge and predictability**
little uncertainty	**rapidly changing**
predictability	**high-level of uncertainty**
(“controlled”artificial worlds)	

Industrial robots vs. natural systems



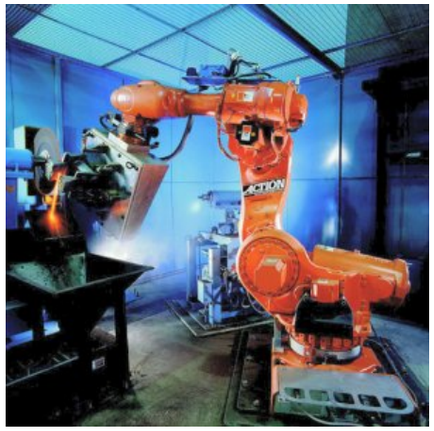
principles:

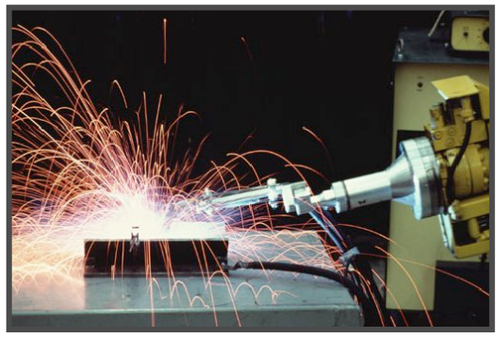
- strong, precise, fast motors

- centralized control

- computing power

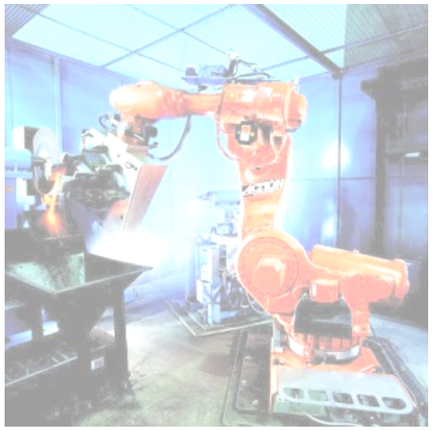
- optimization

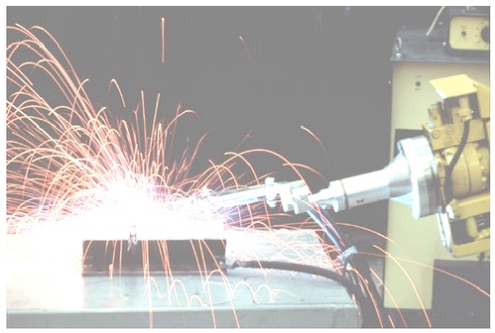




Industrial robots

Industrial robots vs. natural systems





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

humans

no direct transfer of methods

Fundamental problems of classical approach

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

The “symbol grounding” problem

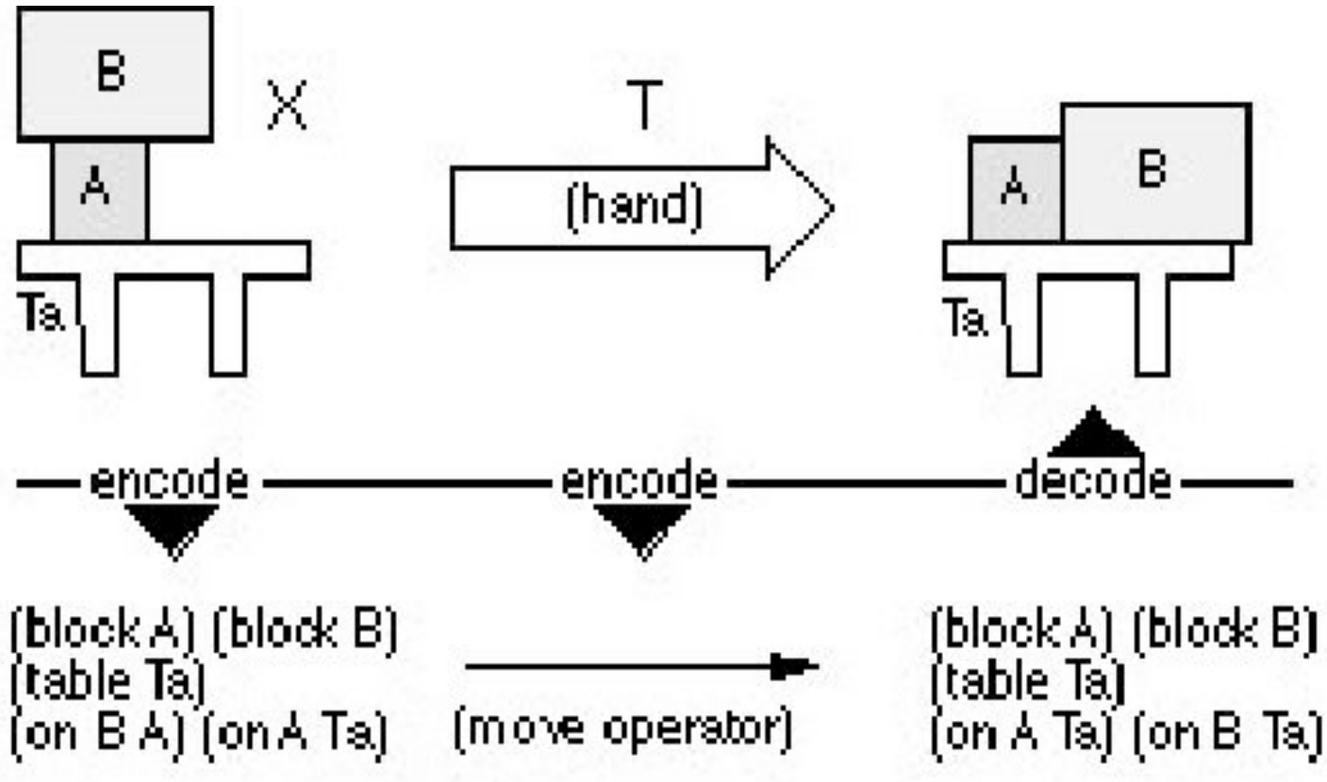
real world: doesn’t come with labels ...

Gary Larson

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

The “frame problem” Maintaining model of real

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



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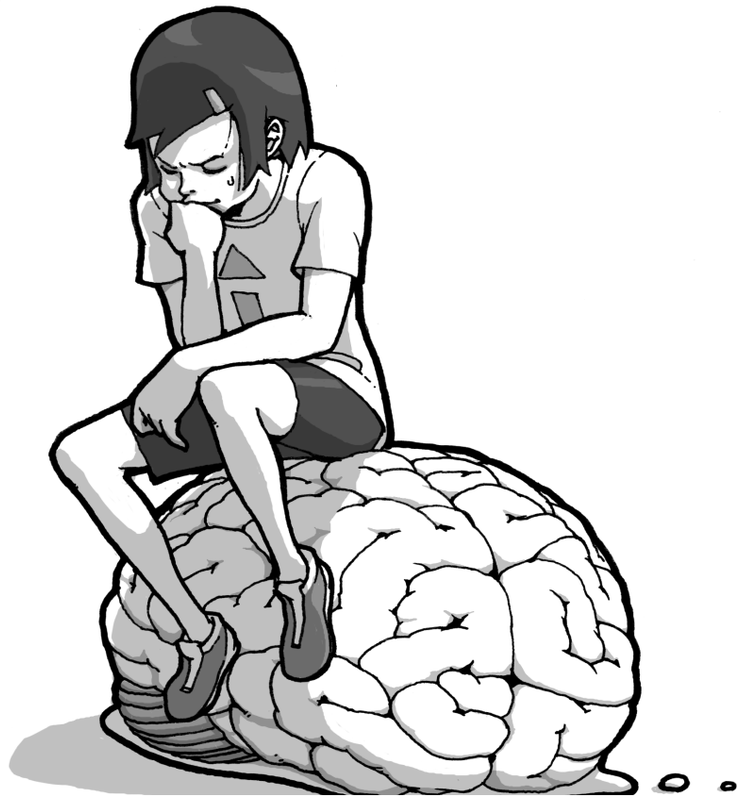
Two views of intelligence

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:

The need for an embodied perspective

“Why do plants not have brains?”

The need for an embodied perspective

"Why do plants not have brains? The answer is actually quite simple — they don't have to move." Lewis Wolpert, UCL

evolutionary perspective on development of intelligence/cognition

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

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The “frame-of-reference” problem — introduction

Video “Heider and Simmel”

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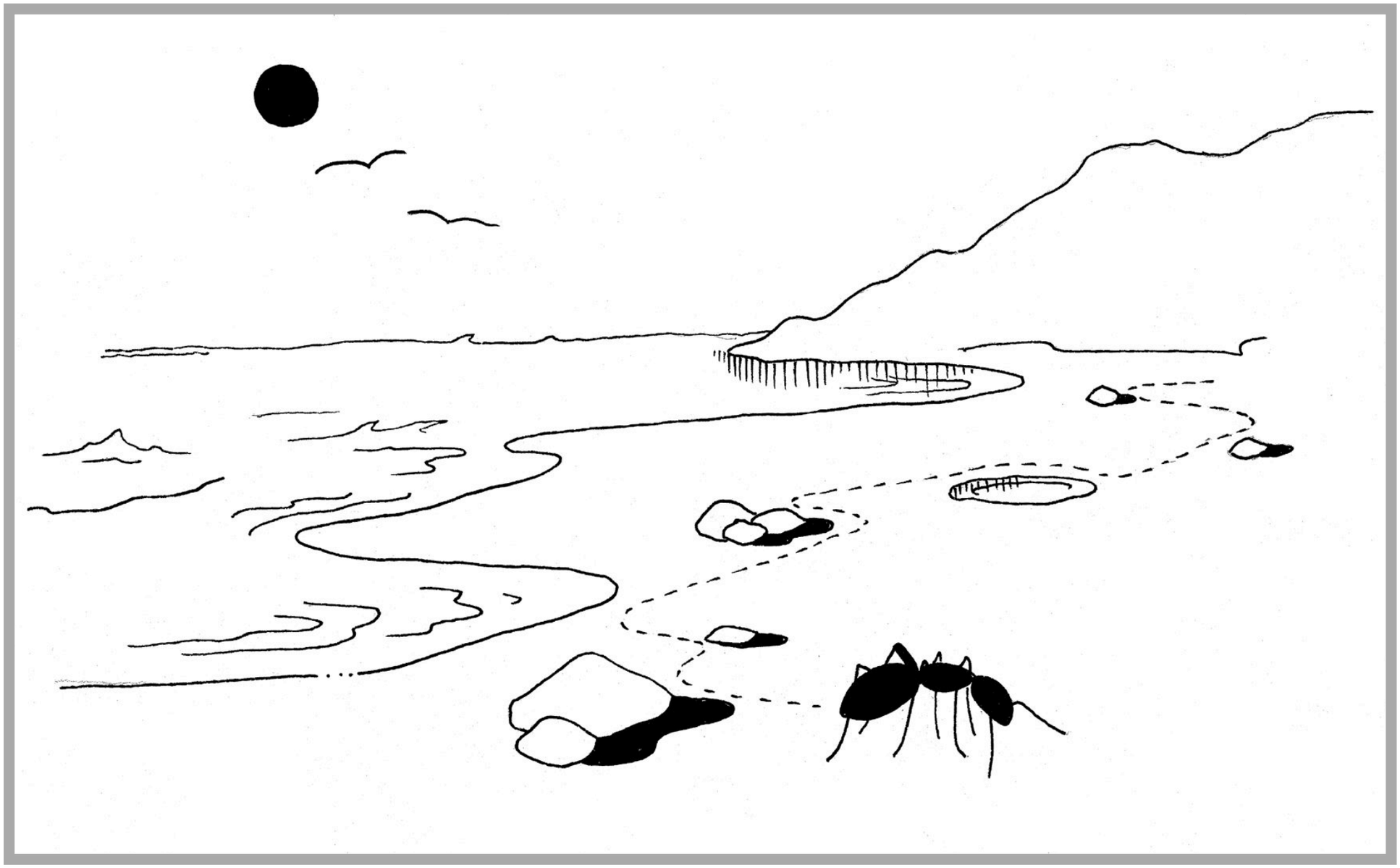
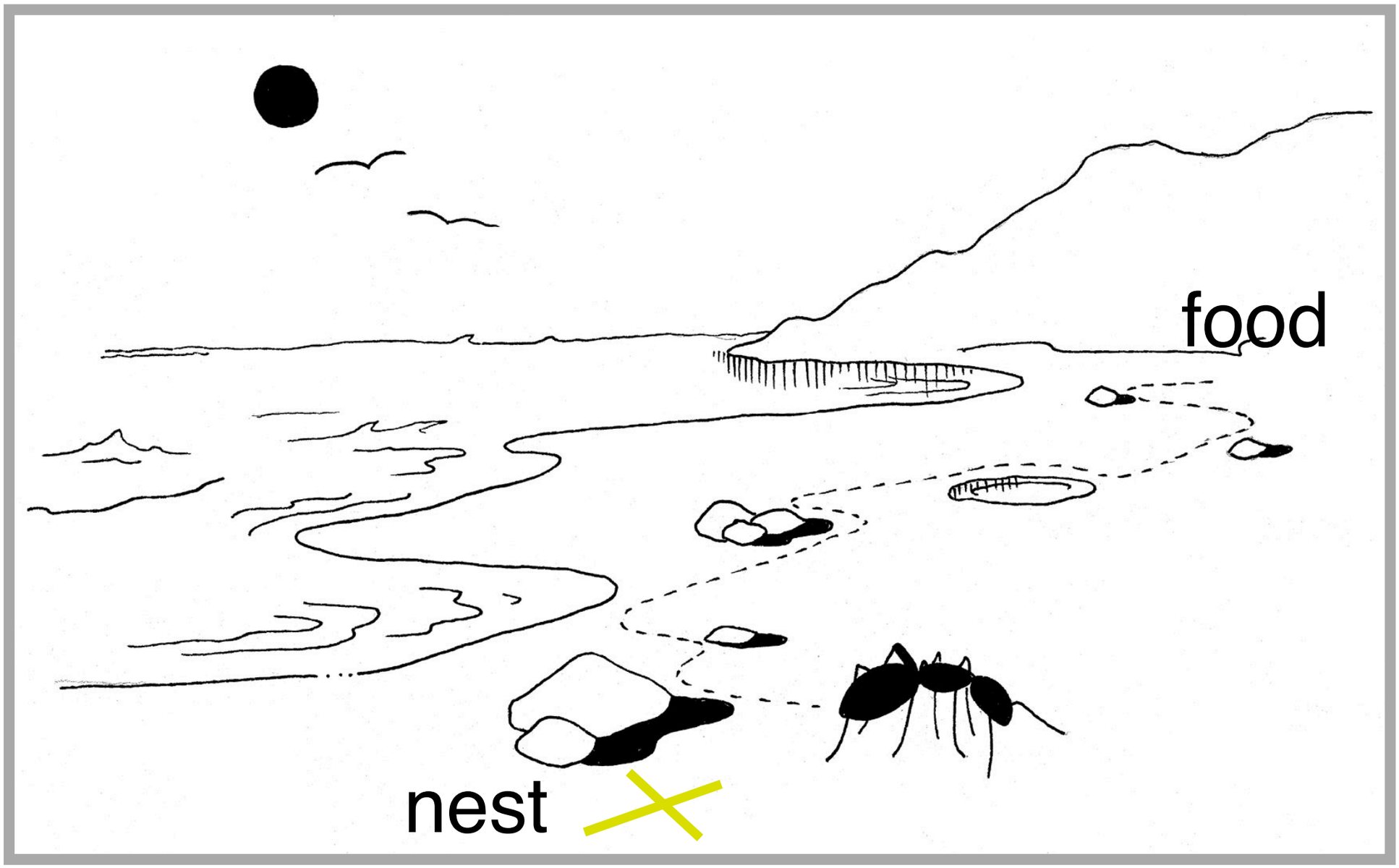
Video “Heider and Simmel”

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



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



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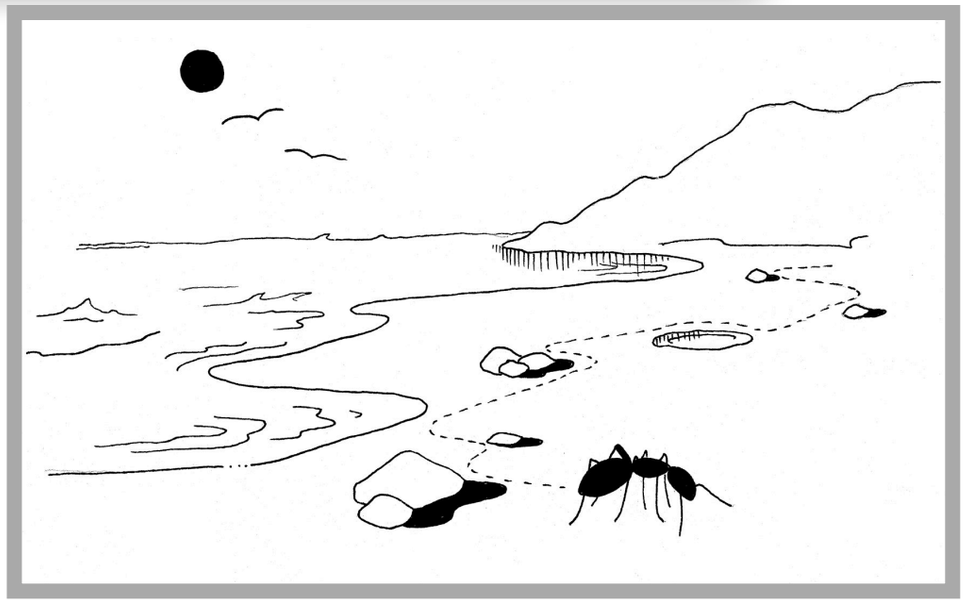
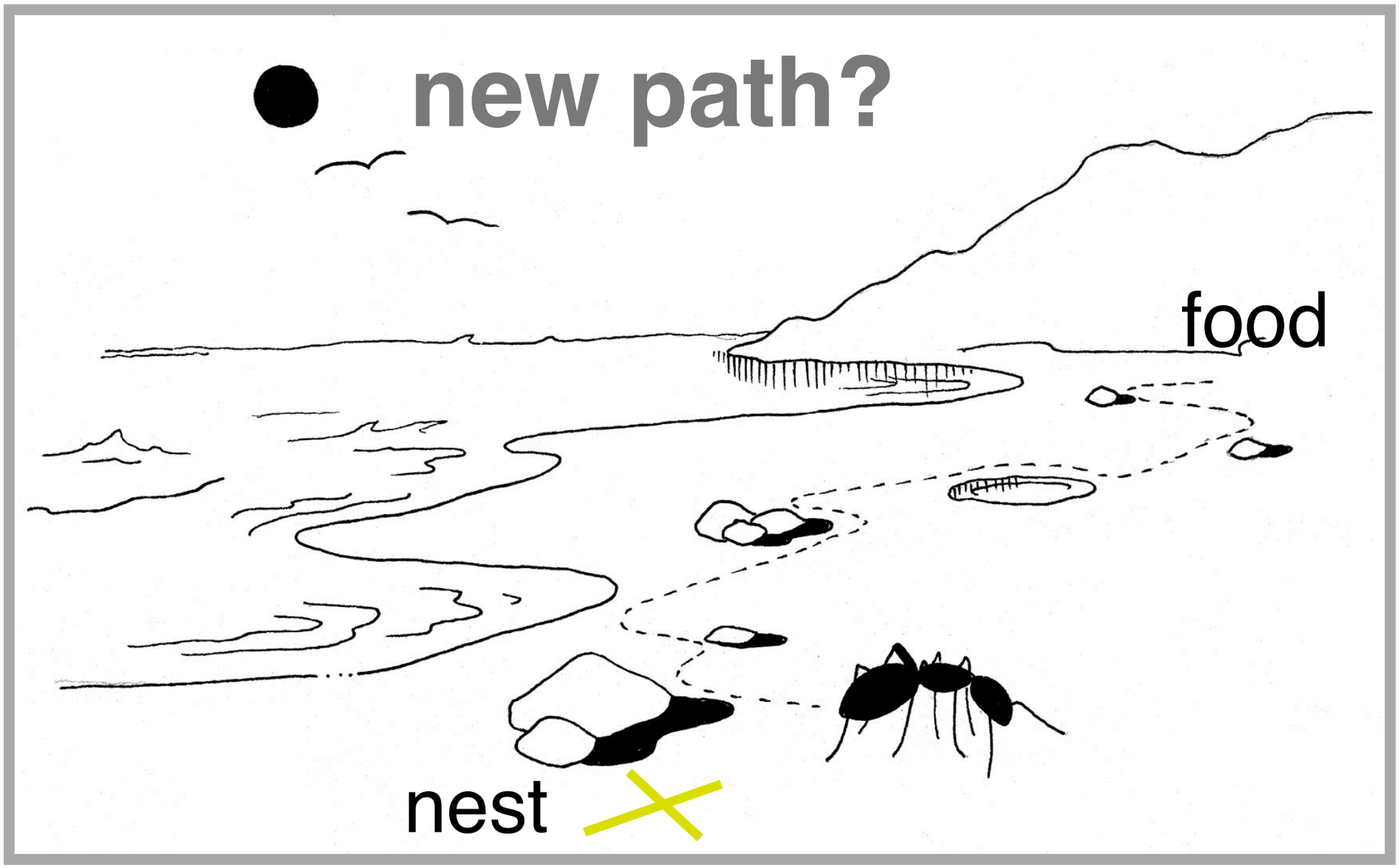


- **simple behavioral rules**
- **complexity in interaction, not — necessarily — in brain**

- thought experiment:
  increase body by factor of 1000

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



“Frame-of-reference”
F-O-R

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

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F-O-R

- perspectives issue
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Intelligence:

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?”

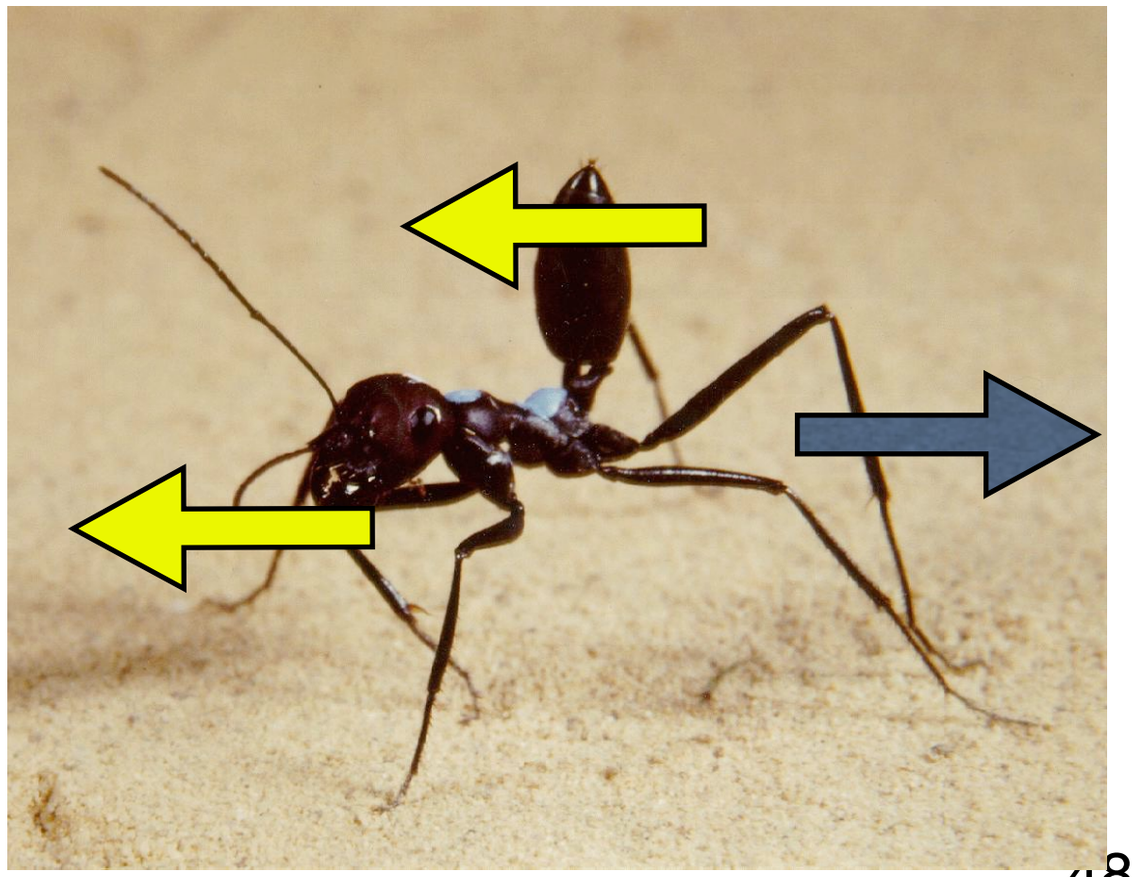
Communication through interaction with

- **exploitation of interaction with environment**

→ **simpler neural circuits**

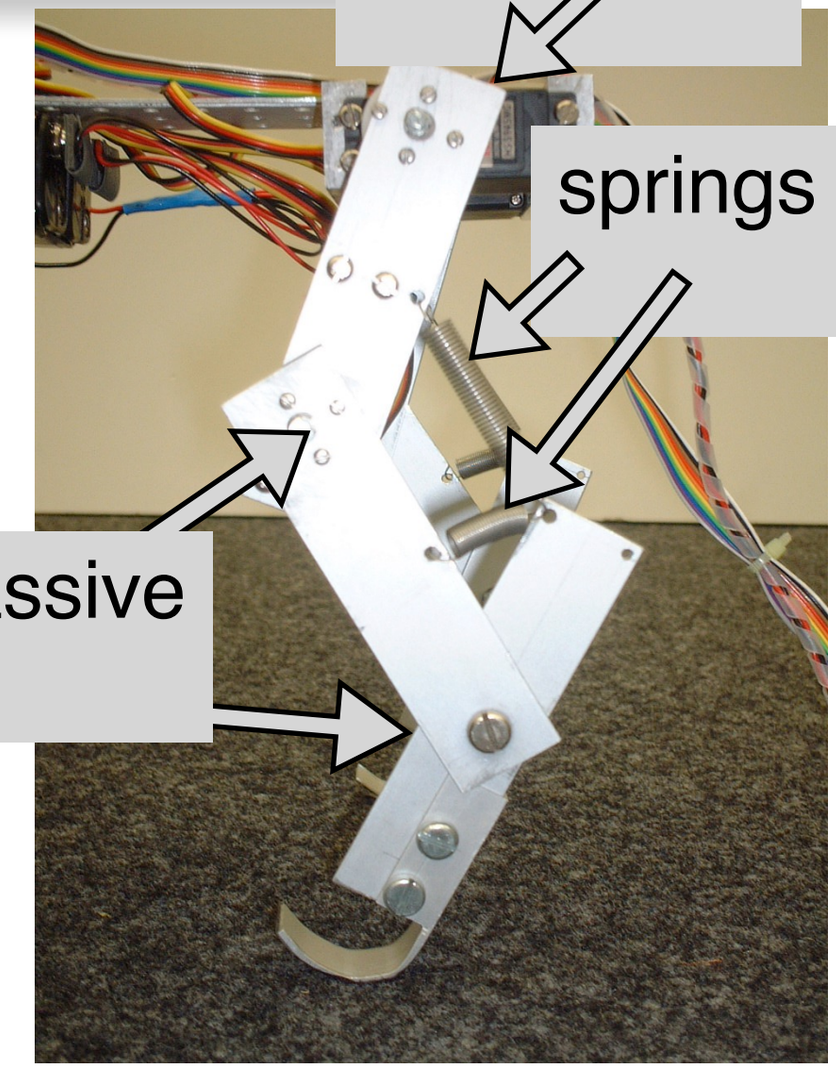
angle sensors in joints

"parallel, loosely coupled processes"



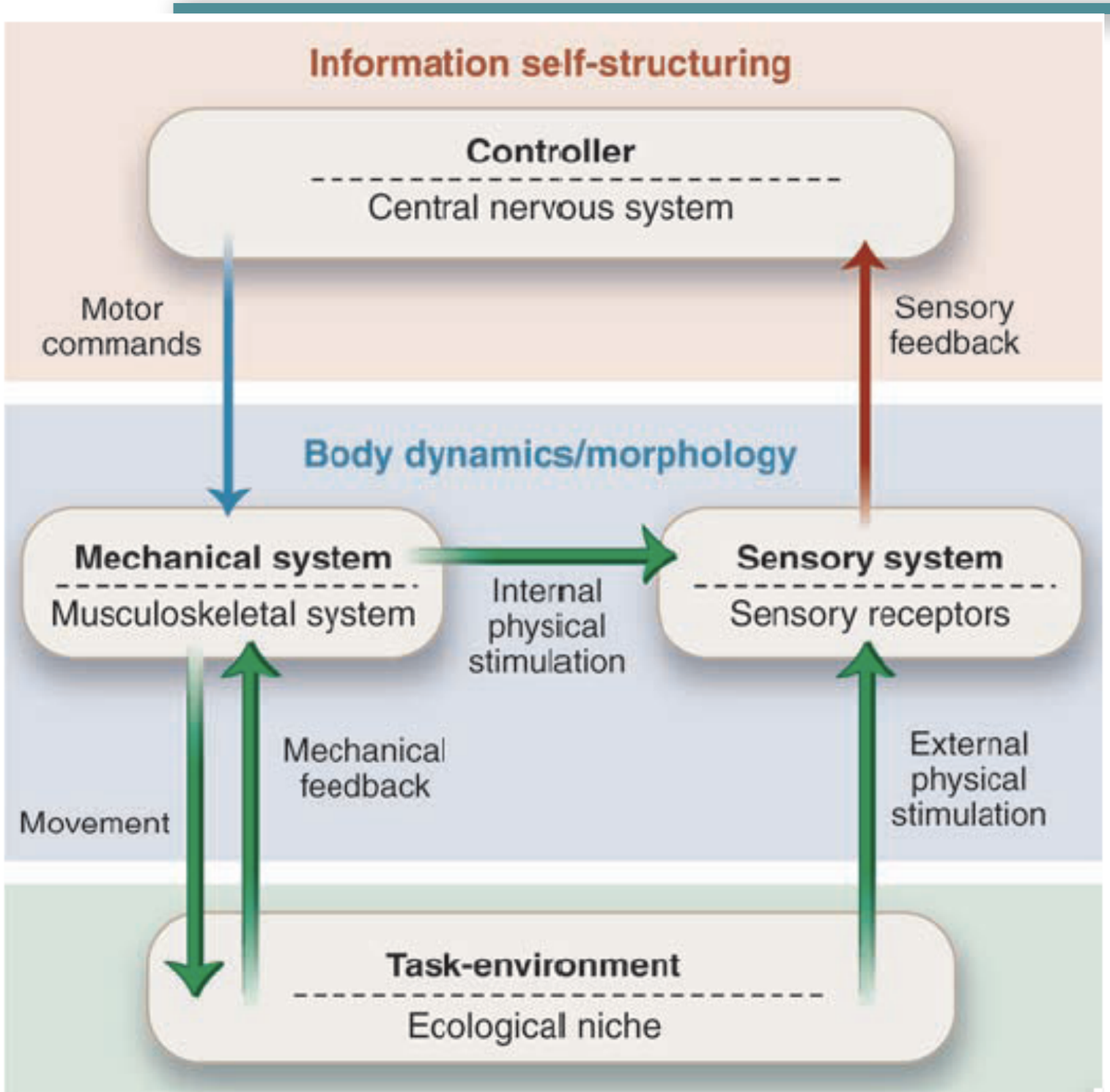
Emergence of behavior: the quadruped “Puppy”

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



morphological computation

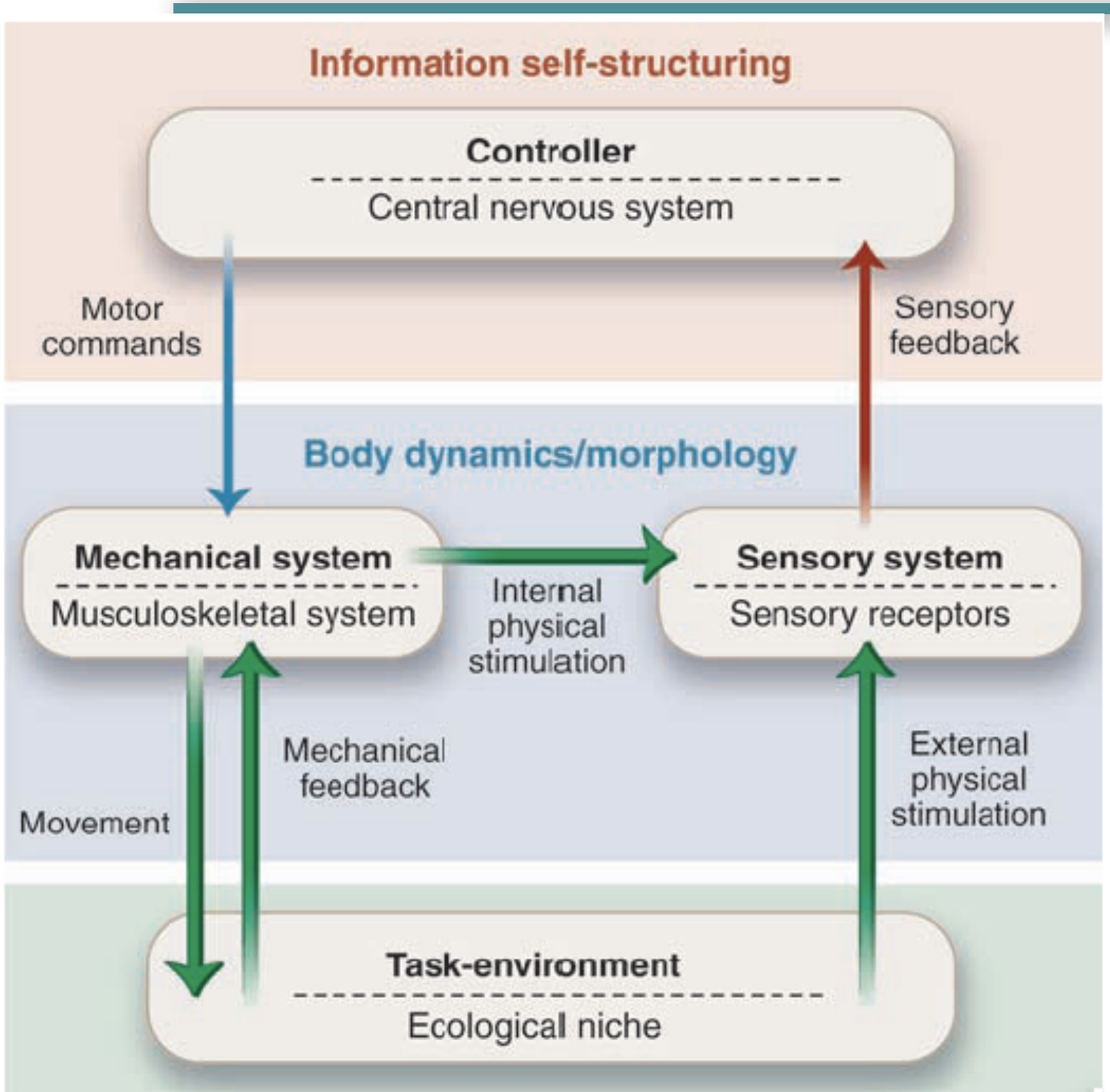
Implications of embodiment



"Puppy", But Also Crus

Pfeifer et al.,Science, 16 Nov. 2007

Implications of embodiment



"Puppy"

which part of diagram is relevant?

—>

Pfeifer et al.,Science, 16 Nov. 2007