Artificial Cognitive Systems

Module 1: The Nature of Cognition

Lecture 2: what is cognition; aspects of modelling cognitive systems:
levels of abstraction and the ultimate-proximate distinction

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Motivation

Recall: there are two reasons people study artificial cognitive systems

1. They want smart systems

2. They want to study cognition

Richard Feynman
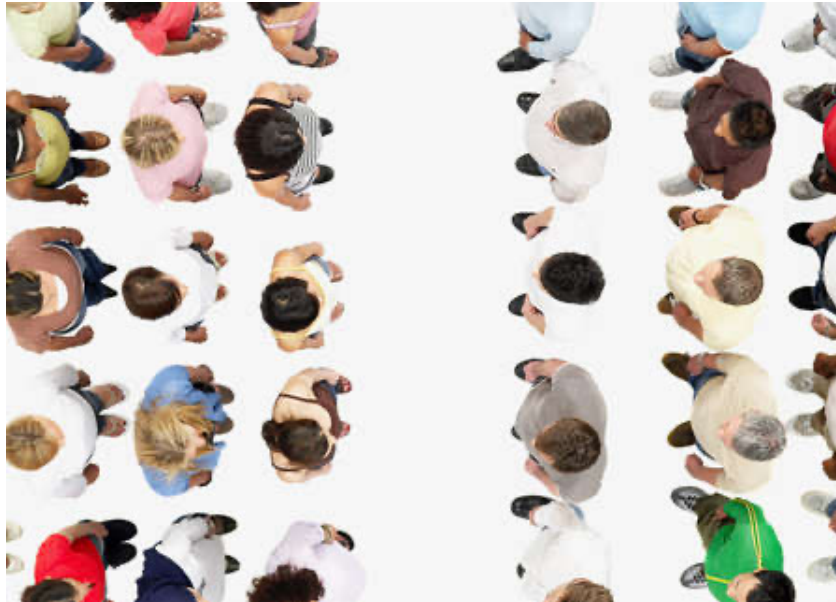
What is cognition?

Non-Cognitive Systems

IEEE Robotics & Automation Society

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Cognitive Robotics

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Cognitive Robotics

Scope:

There is growing need for robots that can interact safely with people in everyday situations. These robots have to be able to anticipate the effects of their own actions as well as the actions and needs of the people around them.

To achieve this, two streams of research need to merge, one concerned with physical systems specifically
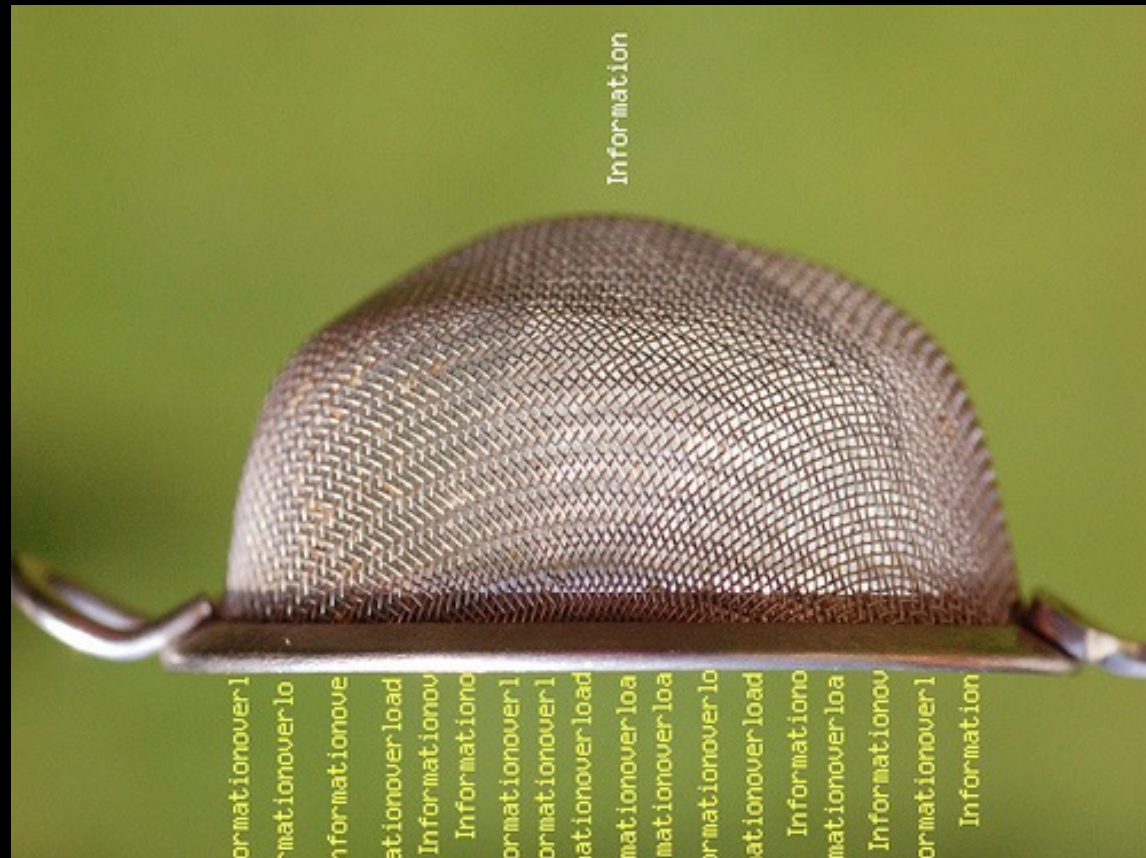
www.ieee-coro.org
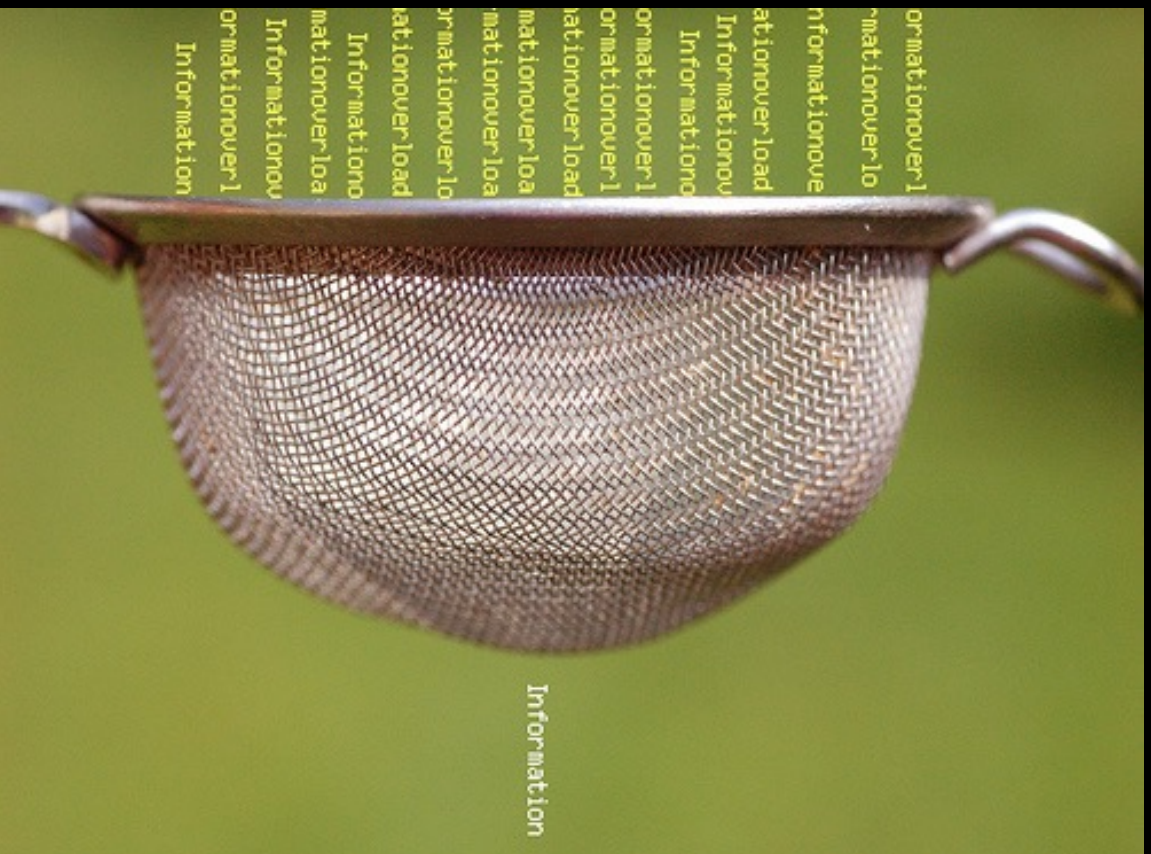
"Cognitive vision is a lot about being able
to assert that something is there,

given very little visual evidence,

and even perhaps despite evidence to the contrary"

Aaron Bobick

This piece of information is the one that is most appropriate in the current context

euCognition

The European Network for the Advancement of Artificial Cognitive Systems

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Definitions of Cognition & Cognitive Systems

The following definitions were contributed by members of euCognition in response to a questionnaire. If you haven't completed the questionnaire, please consider doing so.

The definitions are listed in the order in which they were submitted.

Cognition is the ability to relate perception and action in a meaningful way determined by experience,learning and memory.
Mike Denham

A cognitive system possesses the ability of self-reflection (or at least self-awareness).
Horst Bischof

Cognition is gaining knowledge through the senses.
Majid Mermehdi

Cognition is the ability to ground perceptions in concepts together with the ability to manipulate concepts in order to proceed toward goals.
Christian Bauckhage

An artificial cognitive system is a system that is able to perceive its surrounding environment with multiple sensors, merge this information, reason about it, learn from it and interact with the outside world.
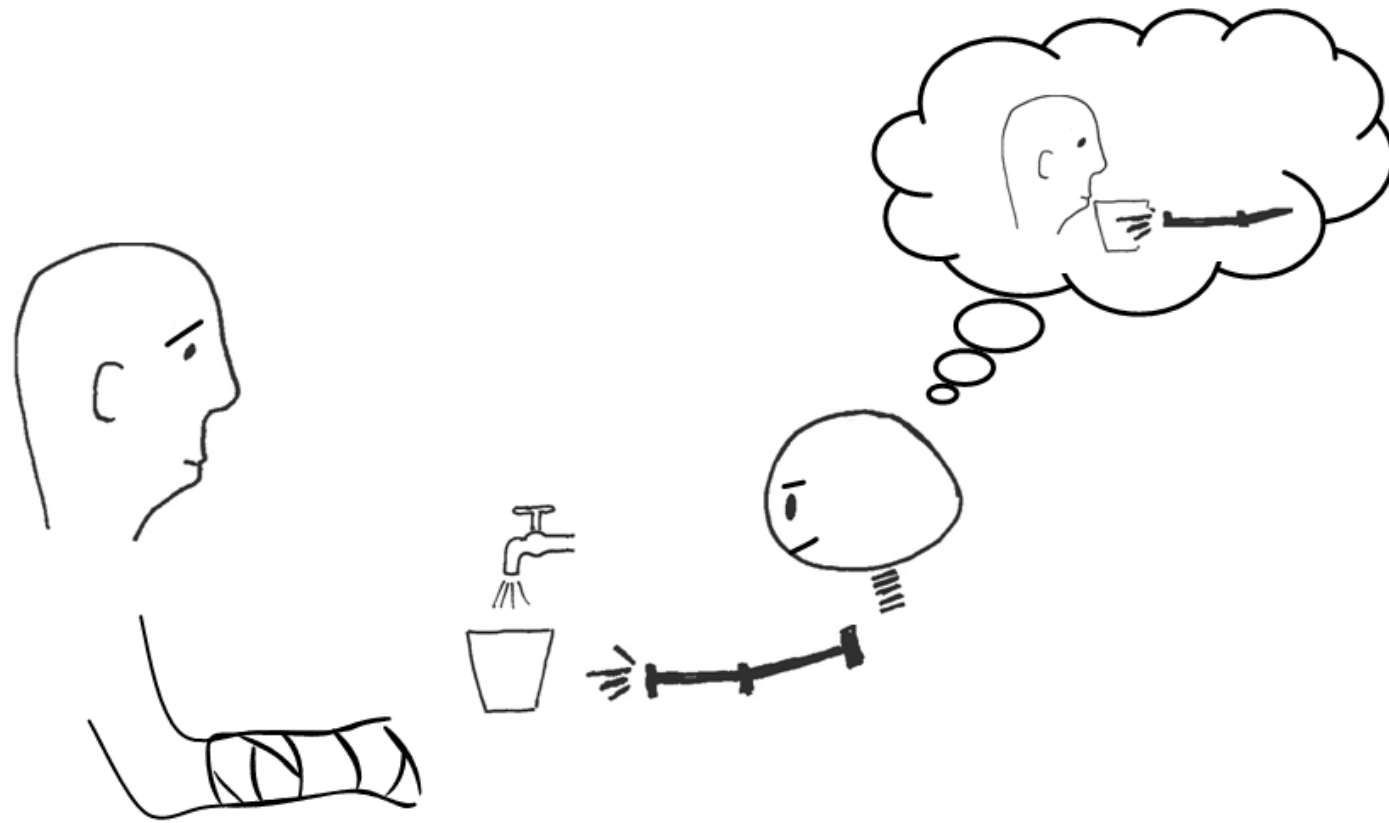Barbara Caputo

42 different definitions

Cognition

"Cognition is the process by which an autonomous system

perceives its environment,

learns from experience,

anticipates the outcome of events,

acts to pursue goals, and

adapts to changing circumstances."

D. Vernon, Artificial Cognitive Systems – A Primer, MIT Press, 2014

Breaking free of the present
(and the limitations of perception)

Cognition is Prospective
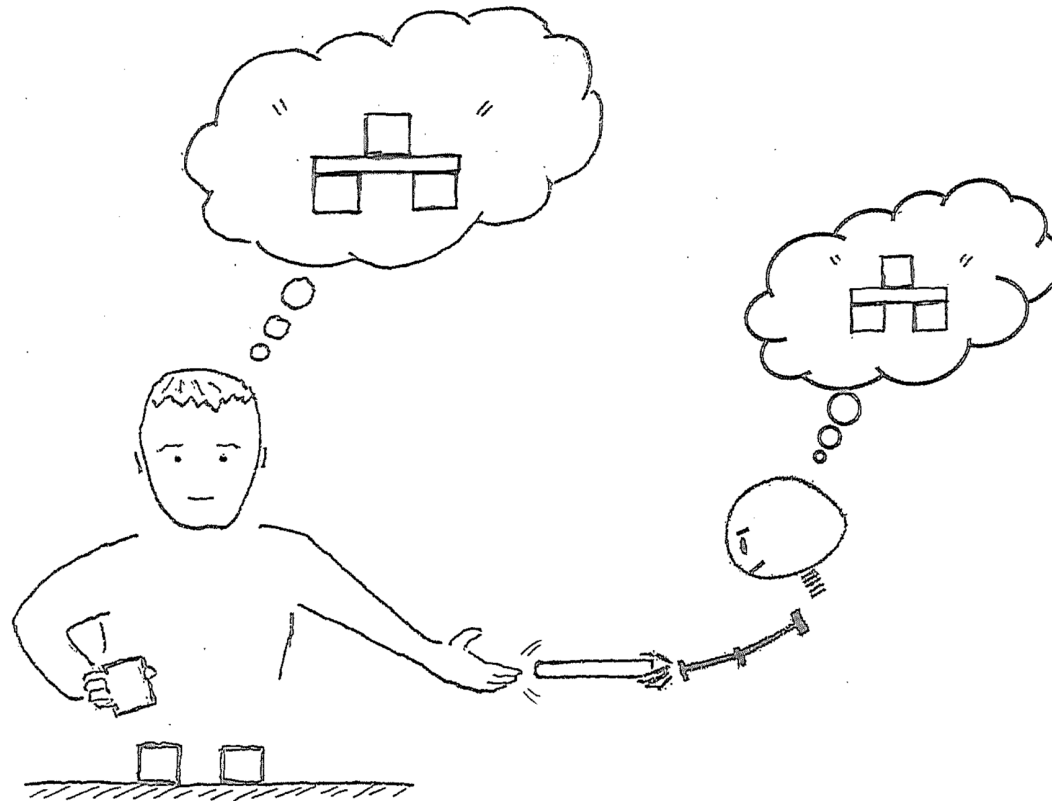
The Future

A system that
continually predicts

The need for actions (self and others)

The outcome of those actions

Cognition

Perception   Action

VS

Cognition

Perception
Learning
Anticipation
Action
Adaptation
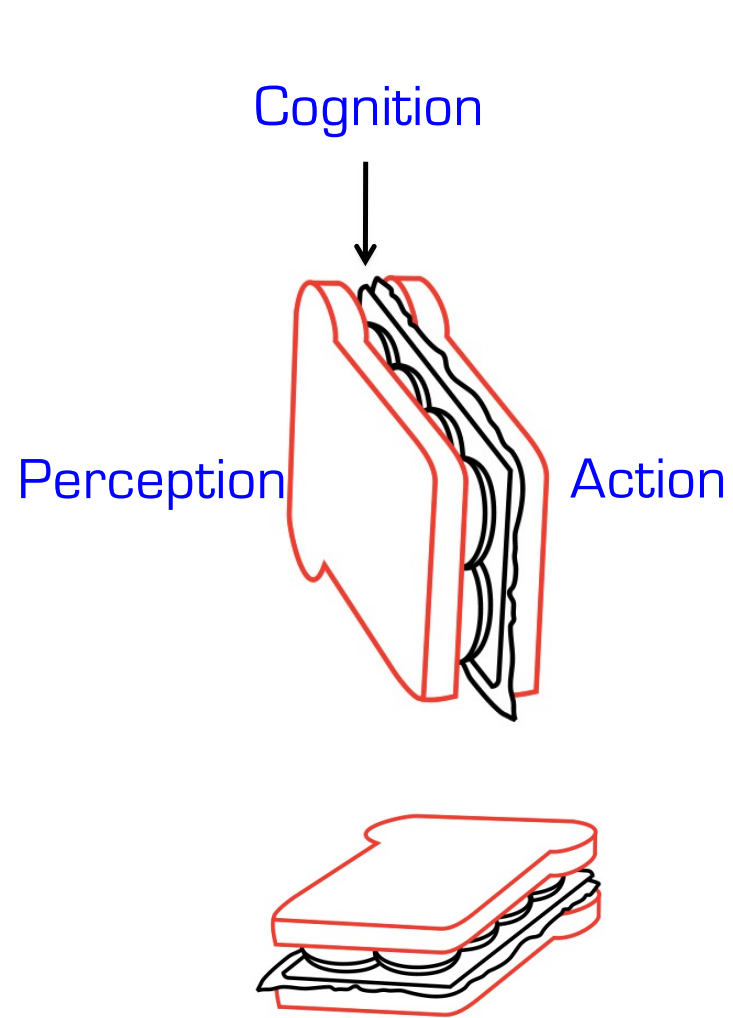
Cognition: guide actions

Missing information

Uncertain information

Changing information

Delayed information

Anticipate (predict what might happen)

Adapt (make sense of the world)
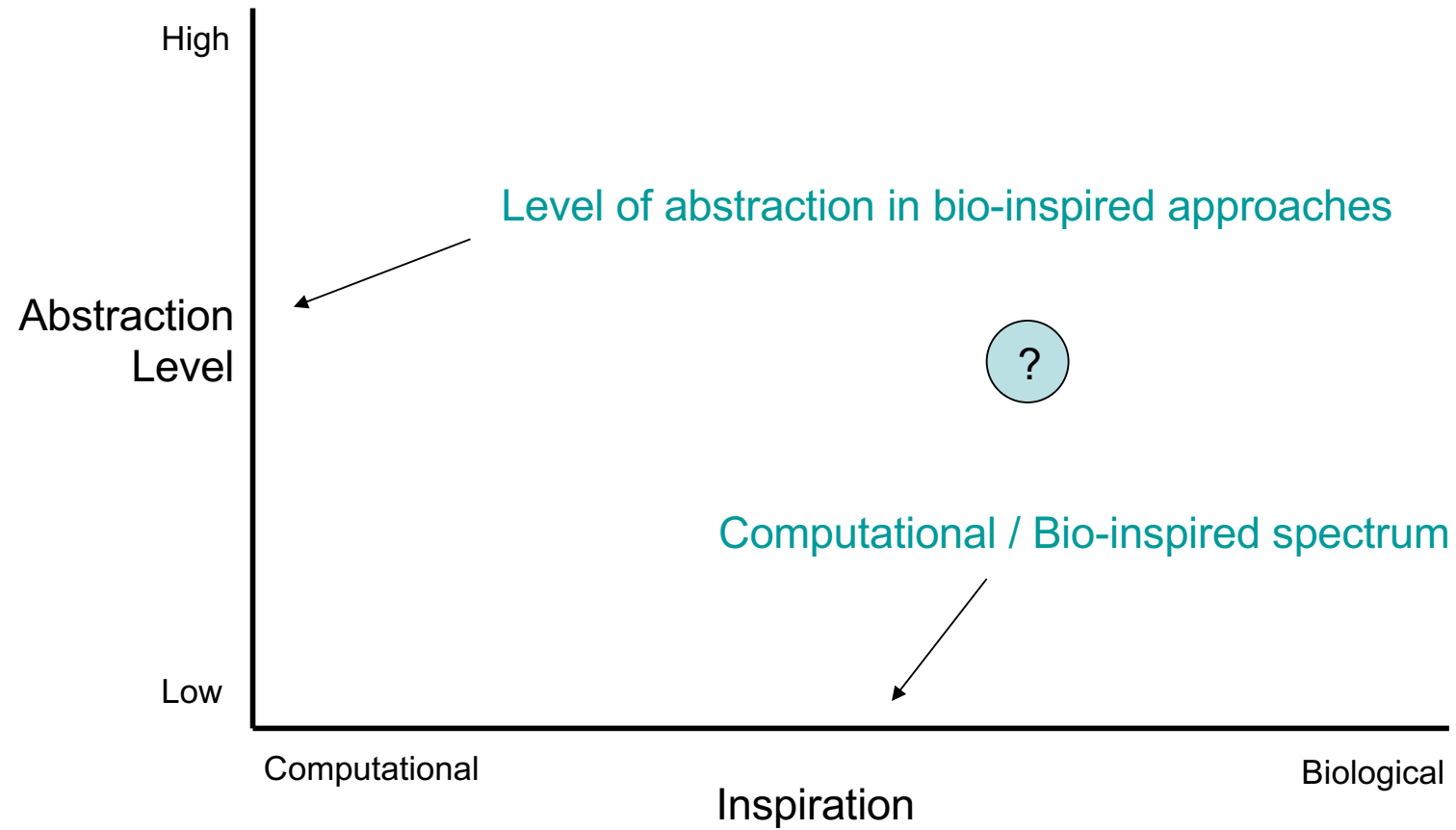
A system that constantly predicts the need for actions

Effective Action

Flexible, context-sensitive action
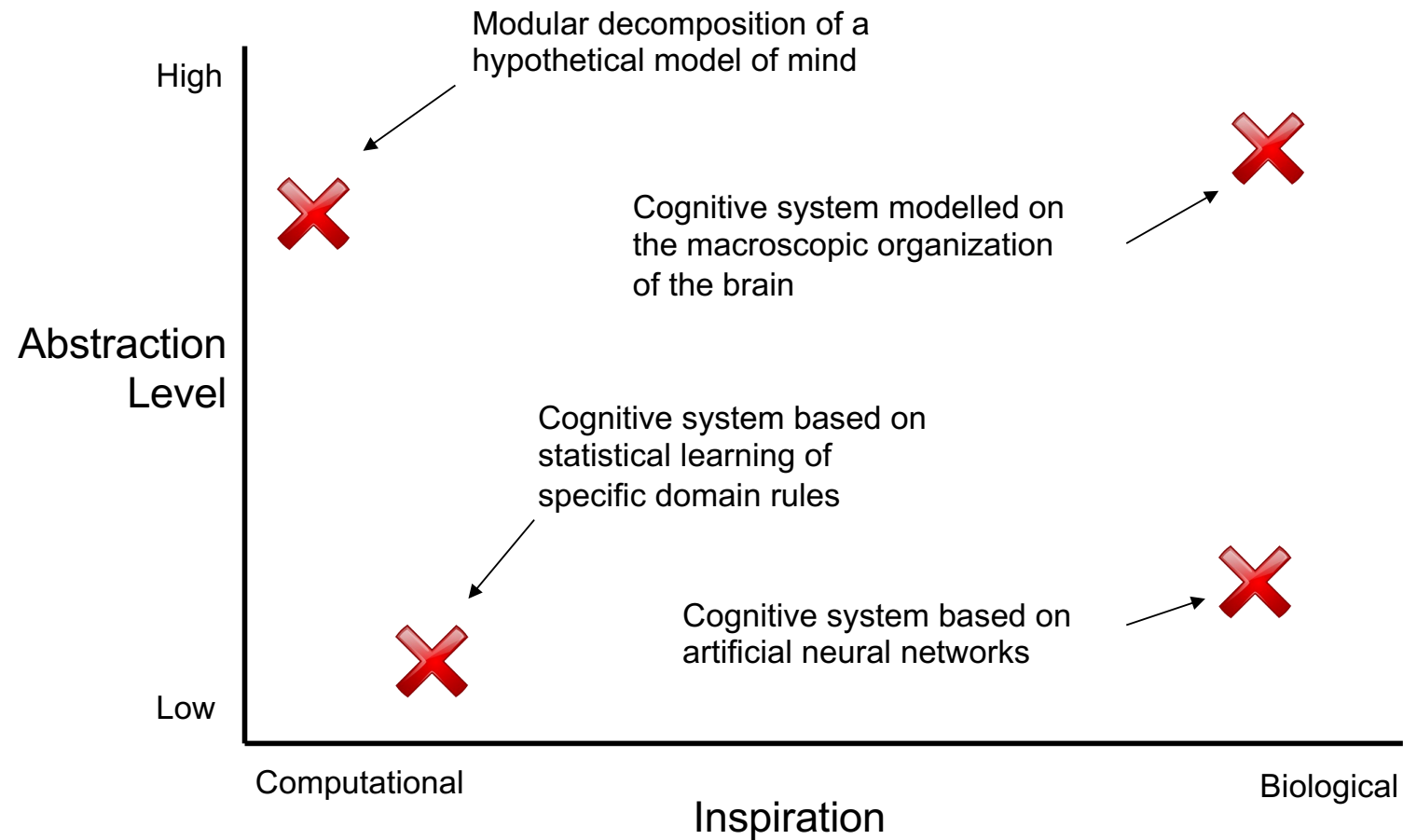
Four Aspects of Modelling Cognitive Systems

The 2D Space of Cognitive Modelling

High

Abstraction
Level

Level of abstraction in bio-inspired approaches

?

Computational / Bio-inspired spectrum

Low

Computational

Inspiration

Biological

The 2D Space of Cognitive Modelling

Modular decomposition of a
hypothetical model of mind

Cognitive system modelled on
the macroscopic organization
of the brain

Cognitive system based on
statistical learning of
specific domain rules

Cognitive system based on
artificial neural networks

High

Abstraction
Level

Low

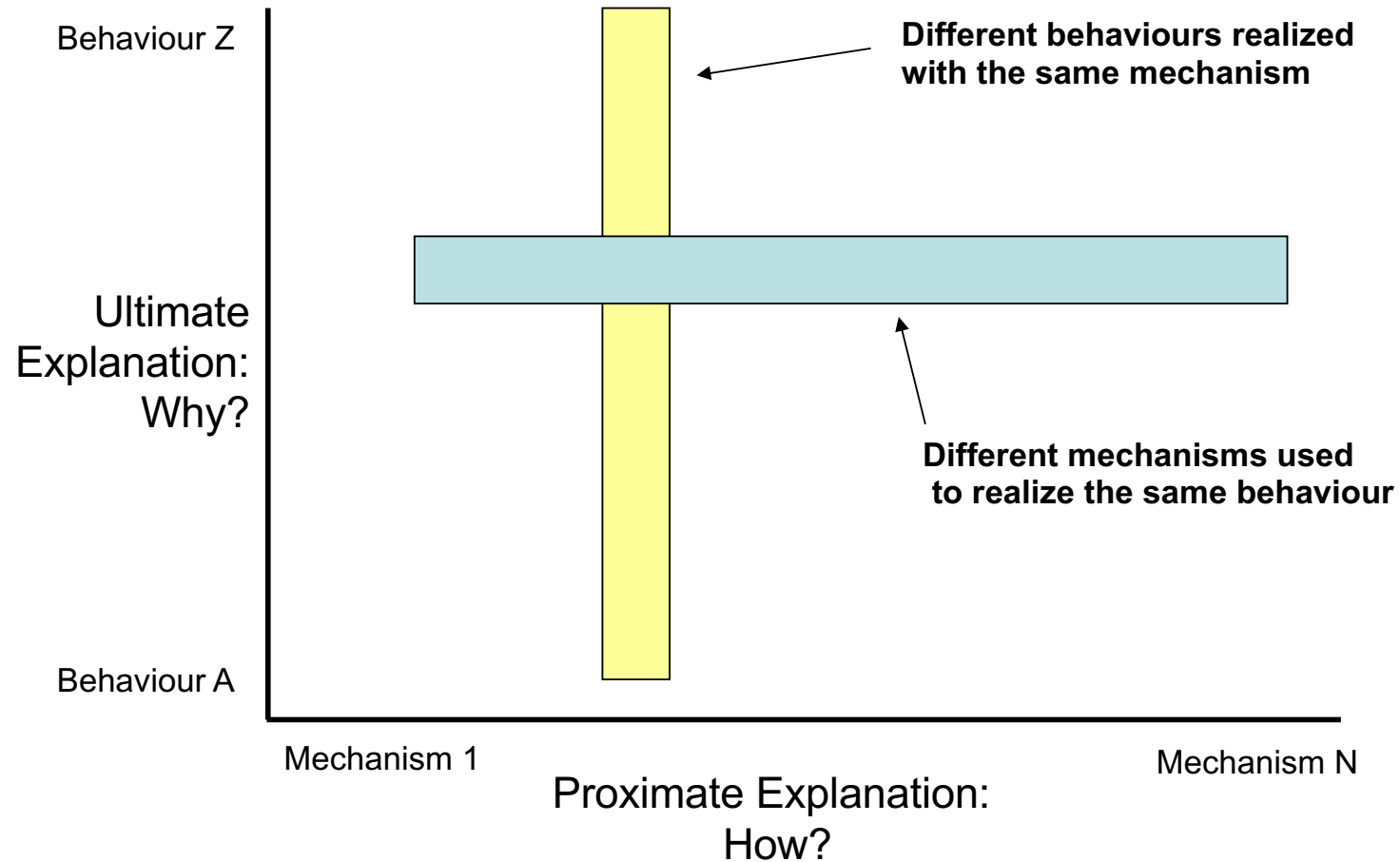Computational

Inspiration

Biological

The Mutual Dependency of
Brain, Body, and Environment

- Brain and cognition is the result of evolution

  – Evolved for a purpose

  – Brain and body evolved together

  – In an ecological niche

- Environment

  – Uncertain and unconstrained

  – But still has some limitation and inherent order/structure

  – Exploited by brain-body system through its cognitive capacities

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The Ultimate-Proximate Distinction

Behaviour Z

Different behaviours realized with the same mechanism

Ultimate Explanation: Why?

Different mechanisms used to realize the same behaviour

Behaviour A

Mechanism 1

Mechanism N

Proximate Explanation: How?

Four Aspects of Modelling
Cognitive Systems

1. The ultimate-proximate distinction;

2. The computational / bio-inspired spectrum;

3. The level of abstraction in the biological model; and

4. The mutual dependence of brain, body, and environment.

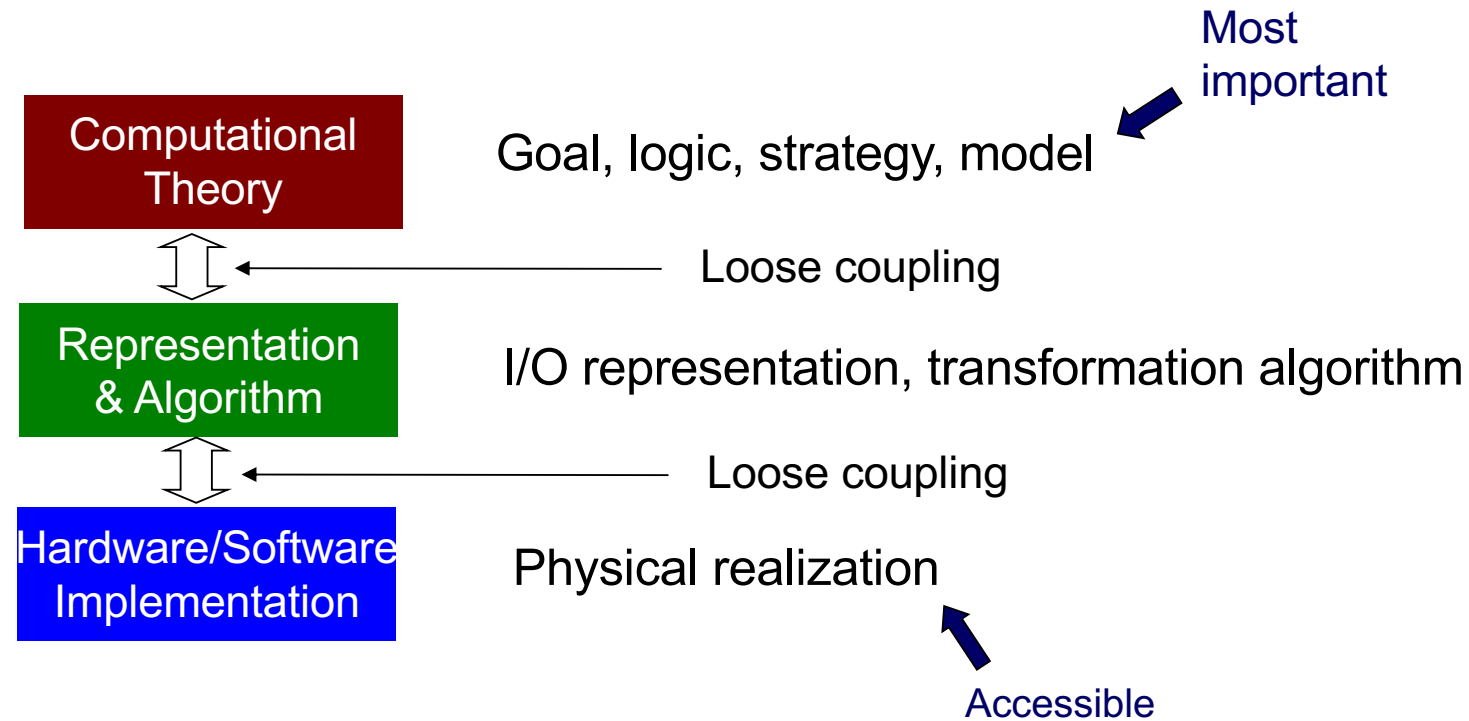# Levels of Abstraction in Modelling Cognitive Systems

Modelling Cognitive Systems

When modelling cognitive systems,

what level(s) of abstraction do we use?

- Marr's hierarchy of abstraction

- Kelso's hierarchy of abstraction

Modelling Cognitive Systems

Marr's hierarchy of abstraction / levels of understanding framework

Computational Theory — Goal, logic, strategy, model — Most important

Loose coupling

Representation & Algorithm — I/O representation, transformation algorithm

Loose coupling

Hardware/Software Implementation — Physical realization — Accessible

Modelling Cognitive Systems
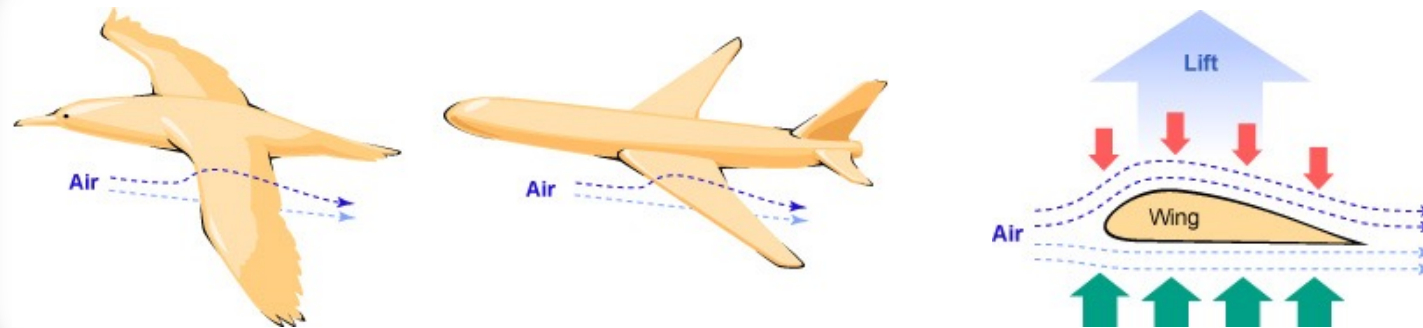
- Marr's hierarchy:

  The problem can, and should, be modelled first at the level of the computational theory without much reference to the lower levels less abstract levels

- Then consider the design options
  (algorithm and representation)

- Then consider the implementation options

Modelling Cognitive Systems

"Trying to understand perception by studying only neurons is like trying to understand bird flight by studying only feathers: it just cannot be done. In order to understand bird flight, we have to understand aerodynamics; only then do the structure of feathers and the different shapes of birds' wings make sense"

Marr, D. *Vision*, Freeman, 1982.

Modelling Cognitive Systems

Kelso's hierarchy of abstraction
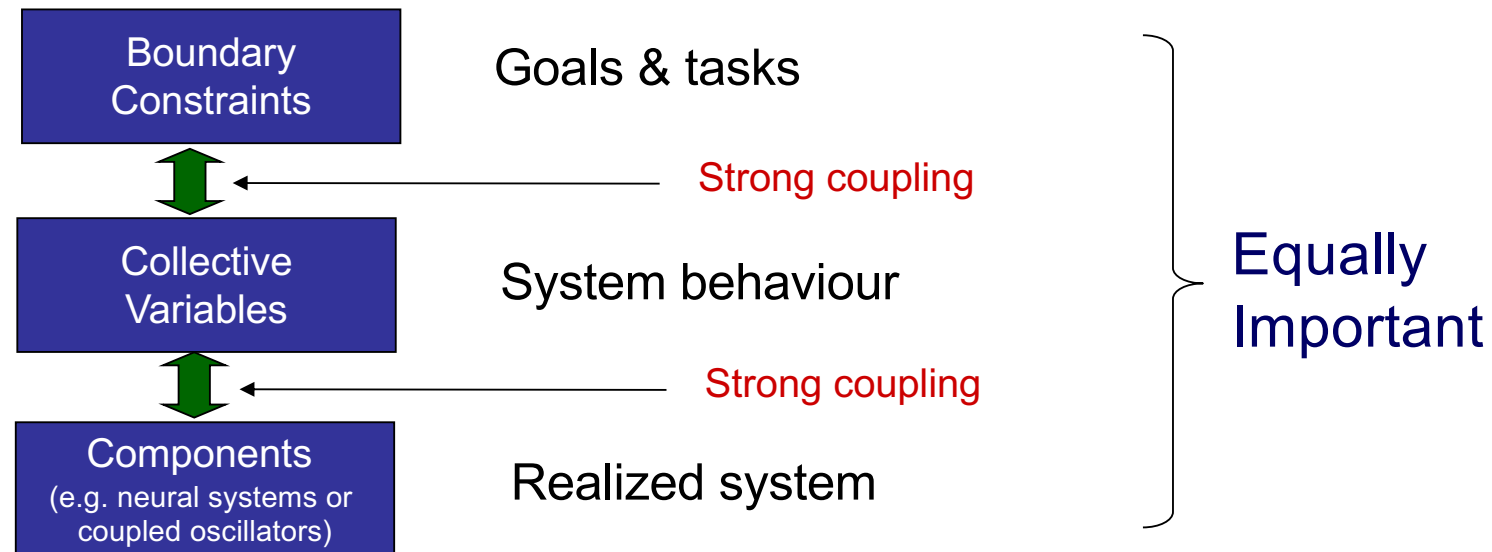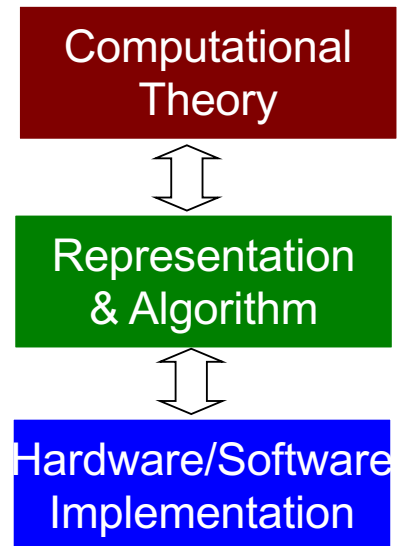
Modelling Cognitive Systems

Kelso's hierarchy:

- Take away the context, and you take away the basis for the model

- Instantiation of the system has a direct role to play in the model itself

- Embodiment is integral to the model
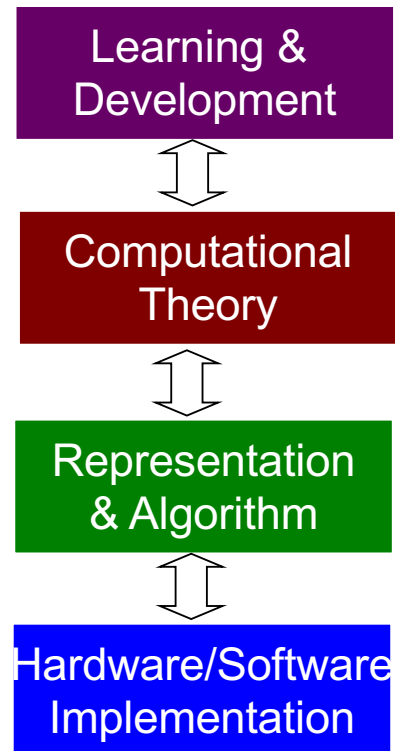
Modelling Cognitive Systems

Marr's hierarchy of abstraction / levels of understanding framework

[Poggio 2012]
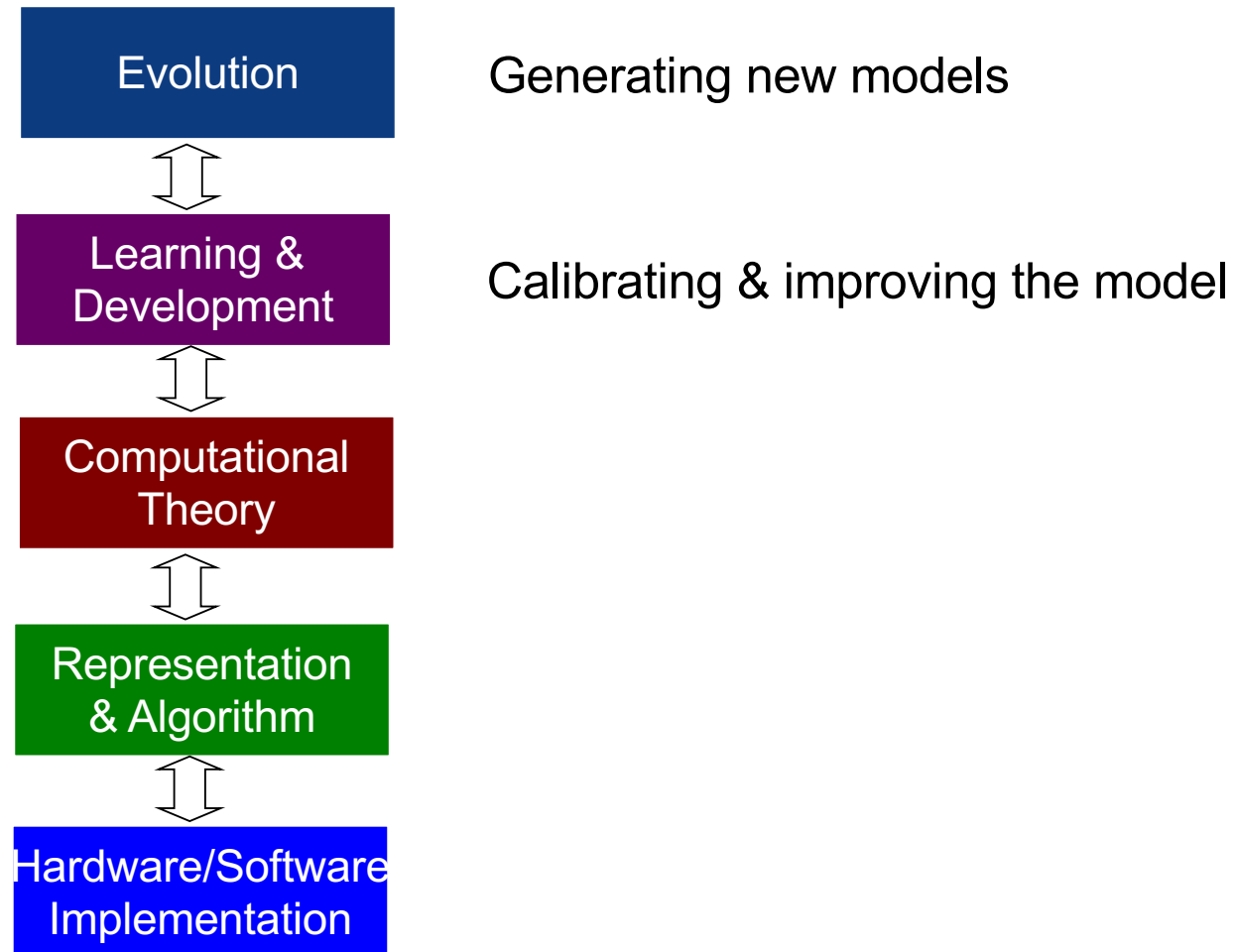
Modelling Cognitive Systems

Marr's hierarchy of abstraction / levels of understanding framework

Calibrating & improving the model

[Poggio 2012]

Modelling Cognitive Systems

Evolution — Generating new models

Learning & Development — Calibrating & improving the model

Computational Theory

Representation & Algorithm

Hardware/Software Implementation

[Poggio 2012]

Reading

D. Vernon, Artificial Cognitive Systems, MIT Press, 2014; Chapter 1.

J. E. Kelly, "Computing, cognition and the future of knowing", White Paper, IBM Corporation, 2015.

Exercise

Prepare a one-page report on (Kelly 2015)

- Summarize the key points

- Compare and contrast these points with the way cognition is presented in the other readings