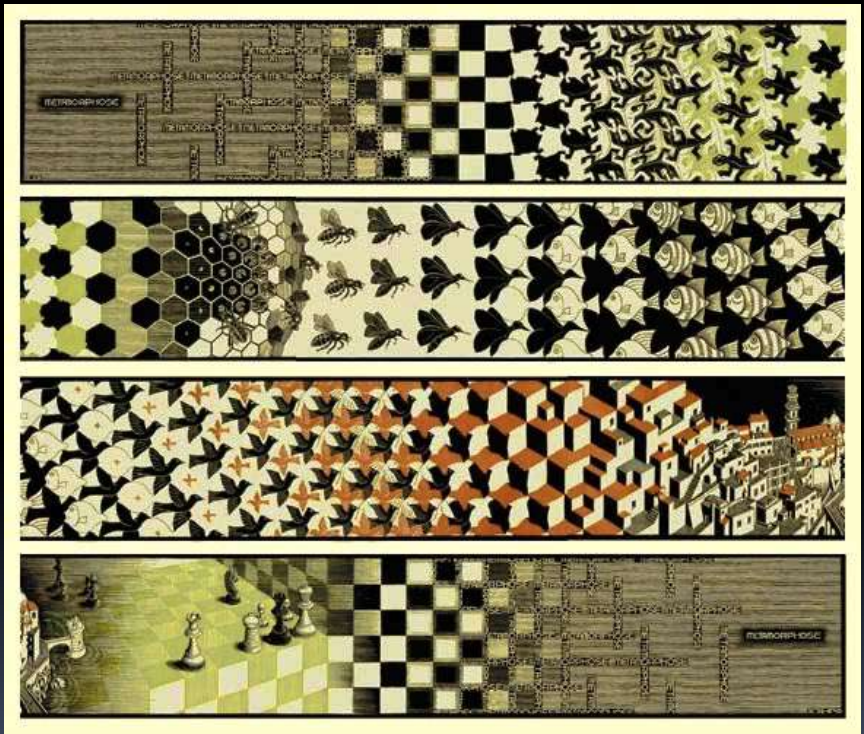
Philosophy & Theory of Artificial Intelligence https://www.pt-ai.org/2011 Thessaloniki 03 10 112011

Info-computational Character of Morpohological Computing



M.C. Escher – Metamorphosis
http://www.globalgallery.com/prod_images/600/esc-e33.jpg

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http://www.mrtc.mdh.se/~gdc

Info-computational Character of Morpohological Computing

- INFORMATION
- COMPUTATION
- MORPHOLOGY

- CONNECTION TO ROBOTICS (AI)
  MODELS vs. METAFORS vs. ANALOGIES)

Information as a Fabric of Reality

"Information is the difference that makes a difference."

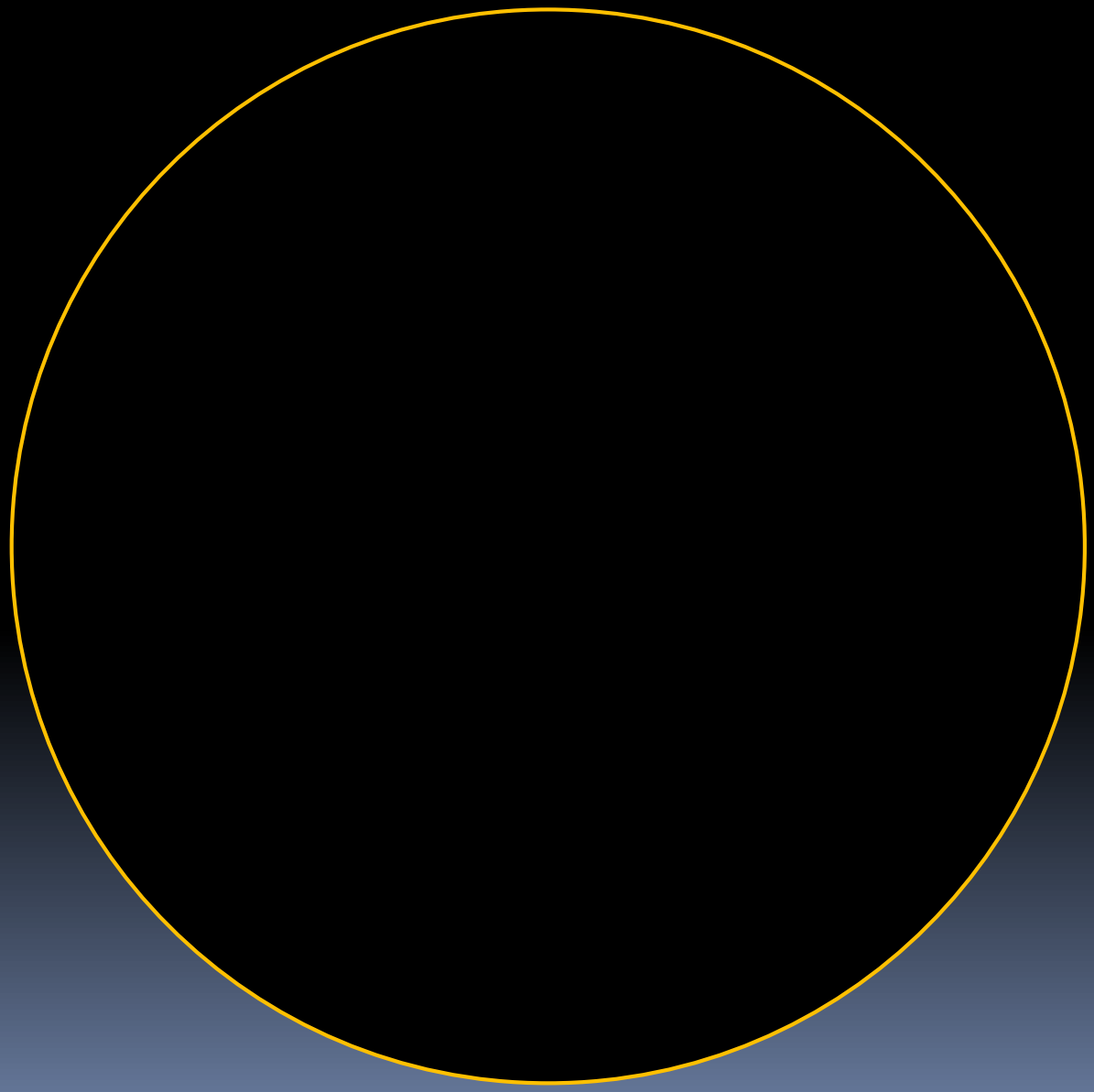
Gregory Bateson

The difference in the world that makes the difference for an agent.

Here world includes agents themselves too.

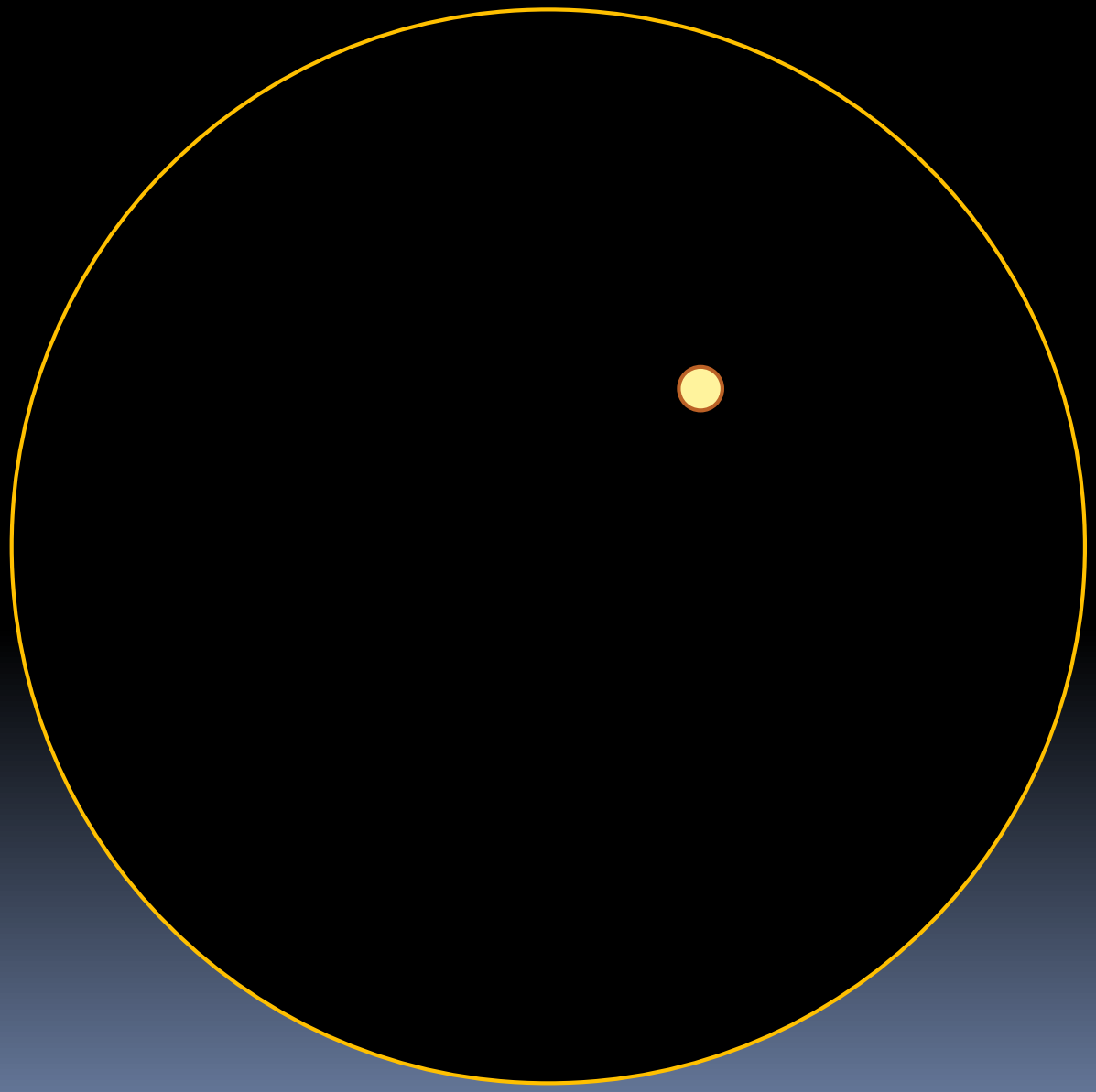
NO DIFFERENCE

(looking through a telescope, microscope, etc)



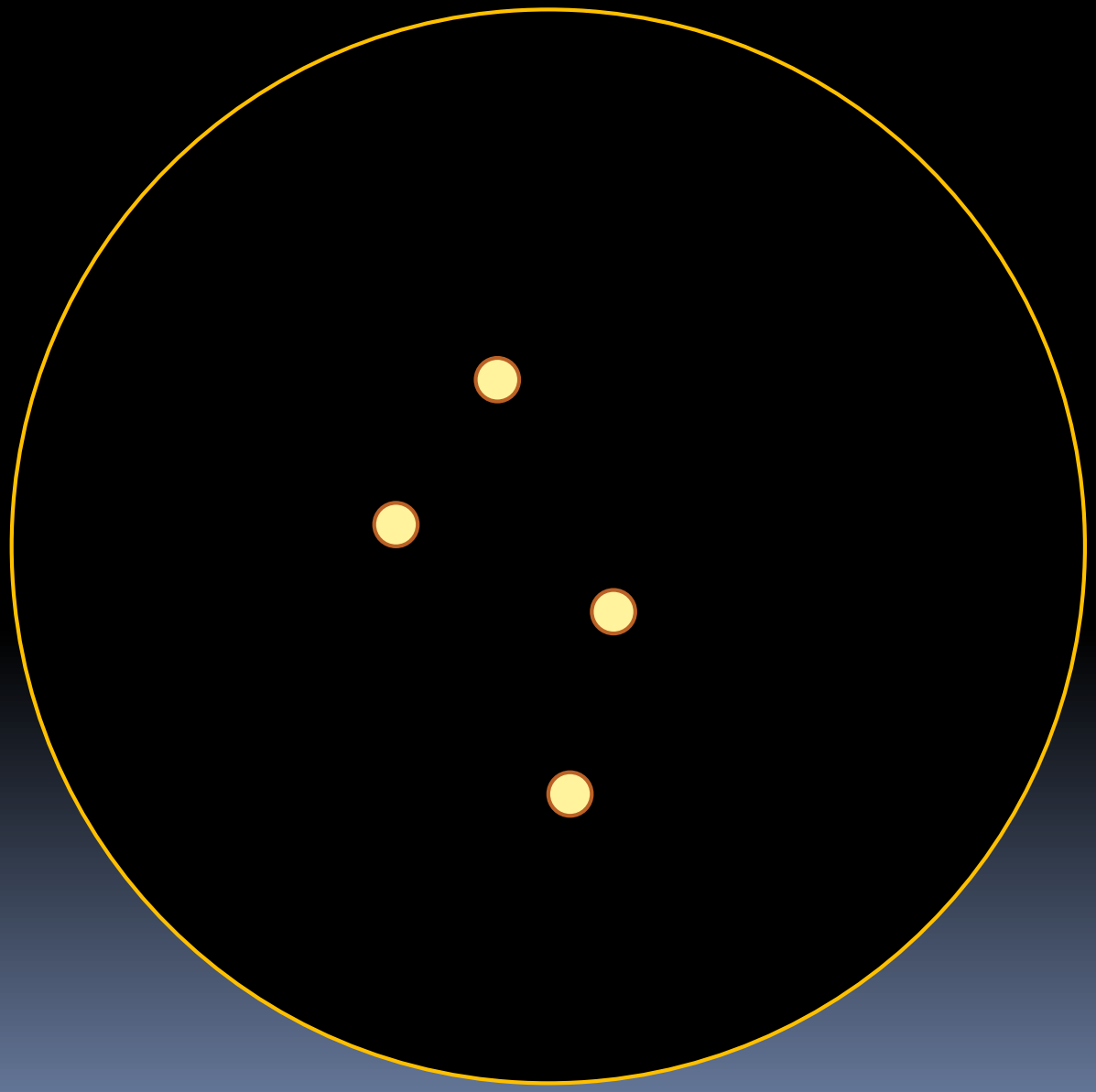
A DIFFERENCE

(that makes a difference for an agent who can see light)



A SYSTEM OF DIFFERENCES

that makes the fabric of reality for an agent



Information as a Fabric of Reality

INFORMATIONAL STRUCTURAL REALISM (Floridi, Sayre)

argues that information is the fabric of reality

(for an agent!)

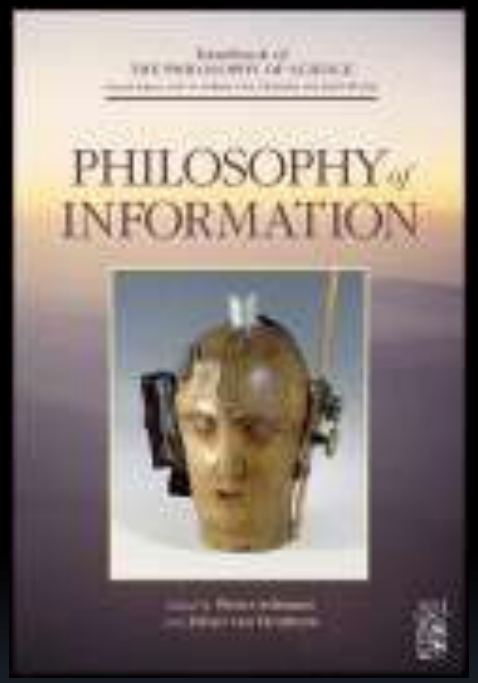
Reality consists of informational structures organized on different levels of abstraction/resolution.

The same view is defended in the book:

Ladyman J. and Ross D., with Spurrett D. and Collier J. (2007)

Every Thing Must Go: Metaphysics Naturalized, Oxford UP,

Information Theory & Philosophy



Philosophy of Information (Van Benthem and Adriaans, 2008), part of the Handbook of the philosophy of science: https://doi.org/10.1016/C2009-0-16481-4

The book shows clearly promises and confusions of the nascent field which successively takes form because of the vacuums and gaps in Information Studies, Information Science and the Philosophy of Information Science.

Structure vs. Process

Building on Informational structural Realism (Floridi, Sayre) we take information as the fabric of reality.

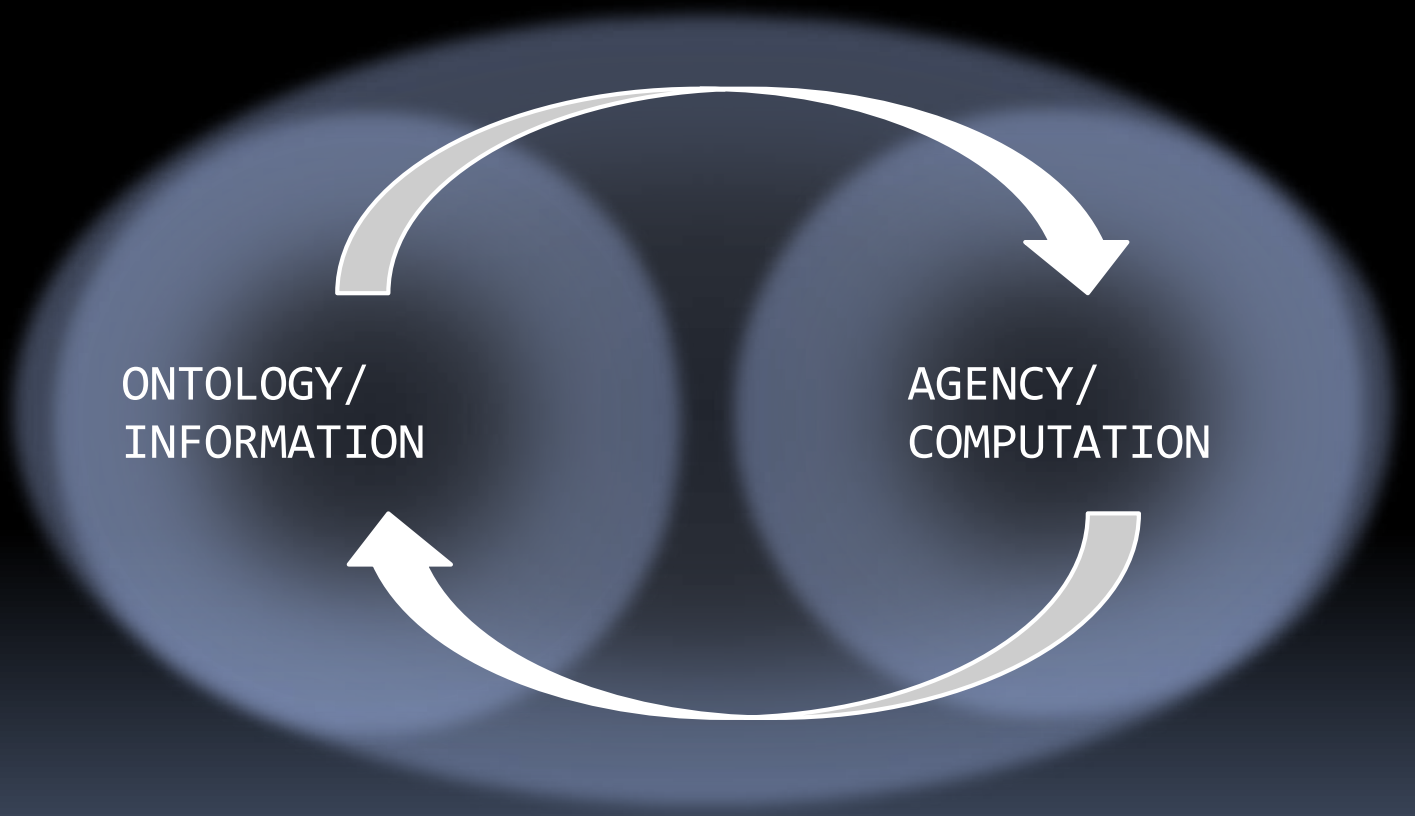
As we can observe, structures in the world constantly change.

The knowledge of structures is half a story.
The other half is the knowledge of processes or information dynamics.

(In classical terms: being and becoming.)

Gordana Dodig-Crnkovic, Dynamics of Information as Natural Computation, Information 2011, 2(3), 460-477; Selected Papers from FIS 2010 Beijing, 2011.

Computing Nature. Dual-Aspect Info-computational Metaphysics



Gordana Dodig-Crnkovic, Investigations into Information Semantics and Ethics of Computing, Mälardalen University Press, 2006

Computing Nature and Nature Inspired Computation

Computation is generally defined as information processing.
Burgin, M., Super-Recursive Algorithms, Springer Monographs in Computer Science, 2005

In 1623, Galileo in his book The Assayer - Il Saggiatore, claimed that the language of nature's book is mathematics and that the way to understand nature is through mathematics. Generalizing "mathematics" to "computation" we may agree with Galileo – the great book of nature is an e-book!

Natural computation includes

Computation Inspired by nature:
Evolutionary computation
Neural networks
Artificial immune systems
Swarm intelligence

Simulation and emulation of nature:
Fractal geometry
Artificial life

Computing with natural materials:
DNA computing
Quantum computing

Models of Computation. Beyond Turing Machine Model

With the advent of computer networks, which are the main paradigm of computing today, the model of a computer in isolation*, represented by a Turing Machine, has become insufficient.

The basic difference between an isolated computing box and a network of computational processes (nature itself understood as a computational mechanism) is the interactivity of computation. The most general computational paradigm today is interactive computing (Wegner, Goldin).

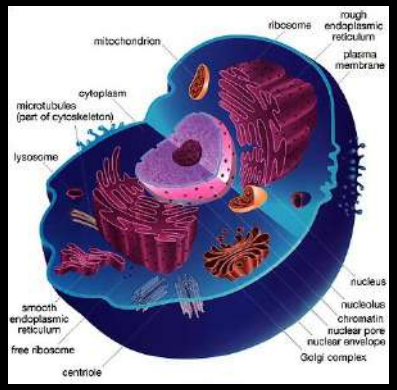
* This view of system in isolation is inherited from physics. I. Prigogine strongly emphasized the important of the environment/context especially essential for living beings.
Prigogine, Ilya; Stengers, Isabelle (1984). Order out of Chaos: Man's new dialogue with nature. Flamingo

Beyond Turing Machine Model

The challenge to deal with computability in the real world - physical computing (natural computing) has brought new understanding of computation.

Natural computing has different criteria for success of a computation, halting problem is not a central issue, but instead the adequacy of the computational response in a network of interacting computational processes/devices.

Models of Computation. Turing Machine Limits. Self-Generating Systems



Complex biological systems must be modeled as self-referential, self-organizing "component-systems" (George Kampis) which are self-generating and whose behavior, though computational in a general sense, goes far beyond Turing machine model.

"a component system is a computer which, when executing its operations (software) builds a new hardware.... [W]e have a computer that re-wires itself in a hardware-software interplay: the hardware defines the software and the software defines new hardware. Then the circle starts again."

(Kampis, p. 223 Self-Modifying Systems in Biology and Cognitive Science)

Dodig Crnkovic, G. (2011) Significance of Models of Computation from Turing Model to Natural Computation. *Minds and Machines*, (R. Turner and A. Eden guest eds.) Volume 21, Issue 2, p.301.

Morphological Computing

Morphological computing is information (re)structuring through computational processes which follow (implement) physical laws.

Morphological computing is physical computing or natural computing in which physical objects perform computation. Symbol manipulation in this case is physical object manipulation.

Info-computationalism - ICON

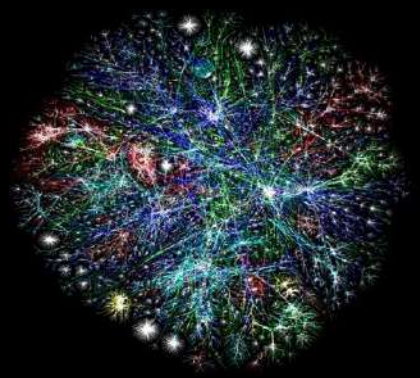
Information and computation are two interrelated and mutually defining phenomena – there is no computation without information (computation understood as information processing), and vice versa, there is no information without computation (information as a result of computational processes).

Being interconnected, information is studied as a structure, while computation presents a process on an informational structure.

In order to learn about foundations of information, we must also study computation.

Gordana Dodig-Crnkovic, Investigations into Information Semantics and Ethics of Computing, Mälardalen University Press, 2006

Info-computational Account of Cognition



Natural computing as a new paradigm of computing goes beyond the Turing Machine model and applies to all physical processes including those going on in our brains.

To do so computer scientists must draw on the expertise in subjects not usually associated with computing, including organic chemistry, molecular biology, bioengineering, smart materials and social cognition etc.

Info-computational Account of Cognition

At the physical level, living beings are open complex computational systems in a regime on the edge of chaos, characterized by maximal informational content. (Flake)

The essential feature of cognizing living organisms is their ability to manage complexity, and to handle complicated environmental conditions with a variety of responses which are results of adaptation, variation, selection, learning, and/or reasoning. (Gell-Mann)

Cognition as Restructuring* of an Agent
in the Interaction with the Environment

As a result of evolution, increasingly complex living organisms arise that are able to survive and adapt to their environment.

It means that they are able to register inputs (data) from the environment, to structure those into information, and in more developed organisms into knowledge.

The evolutionary advantage of using structured, component-based approaches is improving response-time and efficiency of cognitive processes of an organism.

*This restructuring is Morphological computing

Cognition as Restructuring* of an Agent
in the Interaction with the Environment

All cognition is embodied cognition, in both microorganisms and humans. In more complex cognitive agents, knowledge is built upon not only reaction to input information, but also on intentional choices, dependent on value systems stored and organized in agents' memory.

Information and its processing are essential structural and dynamic elements which characterize structuring of input data (data → information → knowledge) by an interactive computational process going on in the agent during the adaptive interplay with the environment.

What Is Computation? How Does Nature Compute? Learning from Nature *

"It always bothers me that, according to the laws as we understand them today, it takes a computing machine an infinite number of logical operations to figure out what goes on in no matter how tiny a region of space, and no matter how tiny a region of time …

So I have often made the hypothesis that ultimately physics will not require a mathematical statement, that in the end the machinery will be revealed, and the laws will turn out to be simple, like the chequer board with all its apparent complexities."

Richard Feynman "The Character of Physical Law"

* 2008 Midwest NKS Conference, Indiana University — Bloomington, IN

MORPHOLOGY AND MORPHOGENESIS

Morphology is the study of form that allows us a rational grasp of the *morphe* (shape) by making internal and external relations intelligible.
It seeks to be a general theory of the formative principles of any structure.

Morphogenesis (from the Greek morphê - shape and genesis - "generation of the shape"), is the biological process that causes an organism to develop its shape.

https://www.youtube.com/shorts/-nKFlPbFJ40 Turing Pattern Formation In Nature

Morphogenesis in Biological Systems

Morphogenesis is studied most frequently in the context of the creation of shape during animal development. It is one of the four fundamental interrelated classes of event that characterize all of development:

Patterning - The setting up of the positions of future events across space at a variety of scales)

Regulation of timing - The 'clock' mechanisms that regulate when events happen. Clocks can directly regulate morphogenesis of individual tissue. Changes of relative timing of events (heterochrony) can drive the evolution of new body plans. (compare to the concept of "real time" in computing)

Cell differentiation: Changes in a cell's set of expressed genes (its molecular phenotype)

http://www.scholarpedia.org/article/Morphogenesis

Morphogenesis as Computation (Information Processing) – Turing's Reaction-Diffusion Model of Morphogenesis

"Patterns resulting from the sole interplay between reaction and diffusion are probably involved in certain stages of morphogenesis in biological systems, as initially proposed by Alan Turing. Self-organization phenomena of this type can only develop in nonlinear systems (i.e. involving positive and negative feedback loops) maintained far from equilibrium." Dulos, E., Boissonade, J., Perraud, J. J.Rudovics, B., Kepper, P. (1996) Chemical morphogenesis: Turing patterns in an experimental chemical system, Acta Biotheoretica, Volume: 44, Issue: 3, pp. 249 -261

Morphological Computation: Connecting Body, Brain, and Environment

soft robotics / self-assembly systems and molecular robotics/

self-assembly systems at all scales / embodied robotics /

reservoir computing / physical reservoir computing/ real neural systems

systems medicine / functional architecture / organization /

process management / computation based on spatio-temporal dynamics/

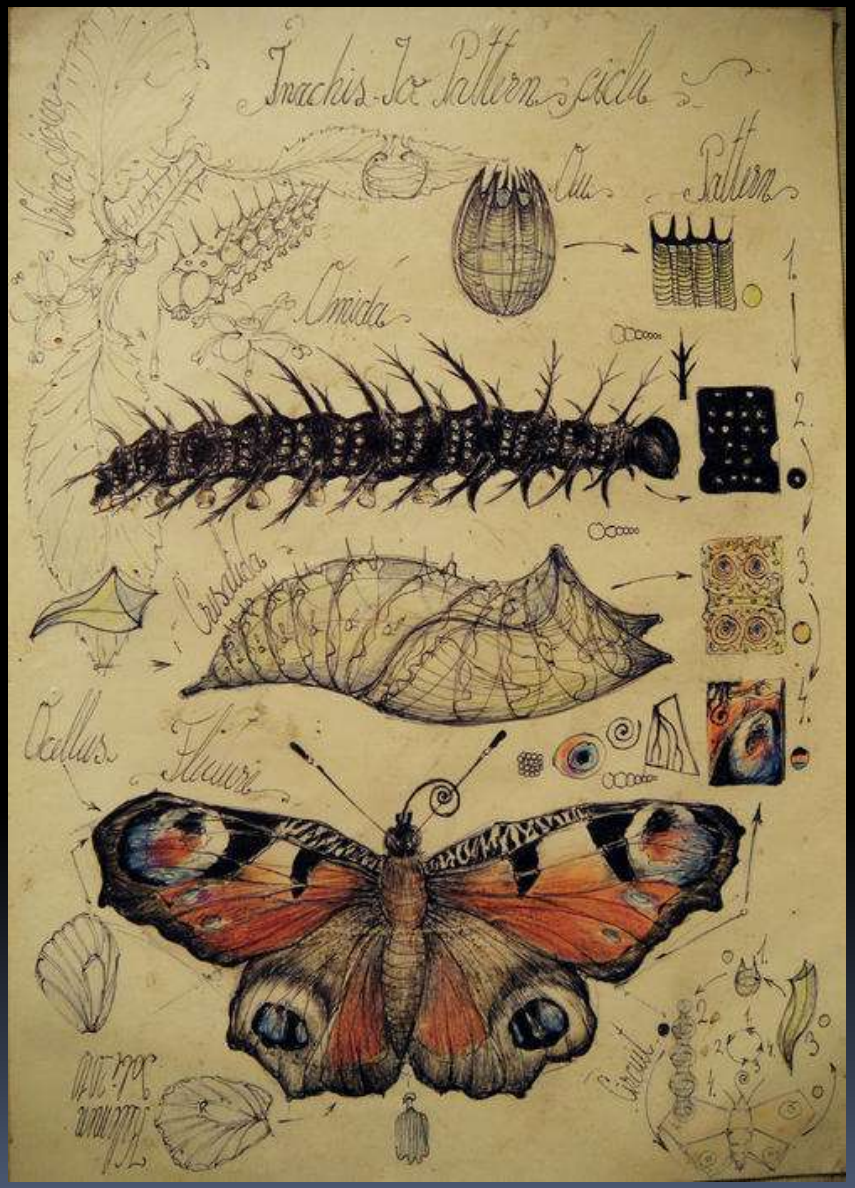
information theoretical approach to embodiment mechatronics /

amorphous computing / molecular computing

http://morphcomp.org/ 2nd International Conference on Morphological Computation ICMC2011.

http://www.eucognition.org/index.php?page=theoretical-scheme Tutorial on Embodiment: R Pfeifer

INFO-COMPUTATIONAL MORPHOGENESIS



Butterfly **morphogenesis** Drawing - Gabriel Kelemen

In an info-computational framework, information is a structure and computation is a process.

Process of computation implements (represents) physical laws.

Through process of computation, structures change their forms.

All of computation on some level of abstraction is morphological computation – a form-changing/ form-generating process.

IS INFO-COMPUTATIONALISM (AND MORPHOLOGICAL COMPUTING) JUST A METAPHOR?

METAPHOR

1. a figure of speech in which a term or phrase is applied to something to which it is not literally applicable in order to suggest a resemblance.

2. something used, or regarded as being used, to represent something else; emblem; symbol.

METAPHOR

A metaphor is a literary figure of speech that uses an image, story or tangible thing to represent a less tangible thing or some intangible quality or idea.

With metaphor, unlike analogy, specific interpretations are not given explicitly.

Life is a roller coaster. She is the light in his life.
He is 24 karat gold. Her eyes were glistening jewels.

ANALOGY

Analogy (from Greek "**ἀναλογία**" – analogia, "proportion") is a cognitive process of transferring information or meaning from a particular subject (the analogue or source) to another particular subject (the target), and a linguistic expression corresponding to such a process.

In a narrower sense, analogy is an inference or an argument from one particular to another particular, as opposed to deduction, induction, and abduction, where at least one of the premises or the conclusion is general.

MODEL

Models are not only a linguistic constructs

They have substantial non-linguistic,

spatio-temporal and visual

interactive qualities.

http://vimeo.com/3764762 Morphogenesis // Processing // Collective Entity

METAPHOR IN SCIENCE

'Perhaps every science must start with metaphor and end with algebra - and perhaps without the metaphor there would never have been an algebra.'

Max Black, Models and Metaphors: Studies in Language and Philosophy, Cornell, Ithaca, 1962

SCIENCE AND MATHEMATICS

Kant heritage

„Ich behaupte aber, daß in jeder besonderen Naturlehre nur so viel eigentliche Wissenschaft angetroffen werden könne, als darin Mathematik anzutreffen ist."

Immanuel Kant: Metaphysische Anfangsgründe der Naturwissenschaft, A VIII

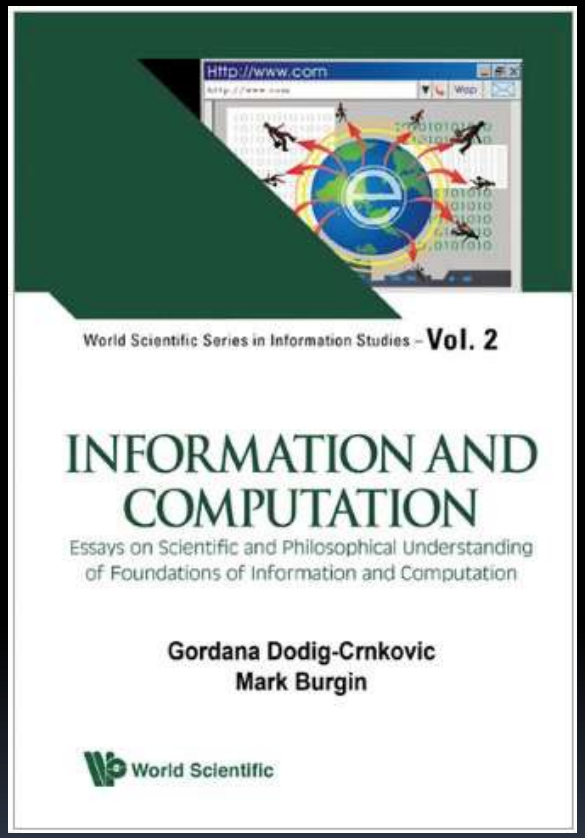
ON THE PRACTICAL SIDE

The process of modeling and creating robots that are more life-like in their morphological properties, can both advance our understanding of biological life and improve embodied and embedded cognition and intelligence in artificial agents .

References

Dodig Crnkovic G, Info-computationalism and Morphological Computing of Informational Structure, Proceeding s of INBIOSA conference, University of Stirling 2011, forthcoming by Springer

Dodig Crnkovic, G. and Müller, V. , A Dialogue Concerning Two World Systems: Info-Computational vs. Mechanistic; in Dodig Crnkovic G and Burgin, M., Eds.; World Scientific Publishing Co., Inc.: Singapore, 2010



Appendix

MORPHOLOGICAL COMPUTING IN ROBOTICS

In recent years, morphological computing emerged as a new idea in robotics, (Pfeifer 2011), (Pfeifer and Iida 2005), (Pfeifer and Gomez 2009) (Paul 2004).

From the beginning, based on the Cartesian traditions, robotics treated separately the body as a machine and its control as a program. However, successively it became evident that embodiment itself is essential for cognition, intelligence and generation of behavior. In a most profound sense, embodiment is vital because cognition results from the interaction of brain, body, and environment. (Pfeifer 2011)

MORPHOLOGICAL COMPUTING IN ROBOTICS

In morphological computing modeling of the agents behavior (such as locomotion and sensory-motor coordination) proceeds by abstracting the principles via information self-structuring and sensory-motor coordination, (Matsushita et al. 2005), (Lungarella et al. 2005) (Lungarella and Sporns 2005) (Pfeifer, Lungarella and Iida 2007).

Brain control is decentralized based on the sensory-motor coordination through the interaction with environment. Through the embodied interaction with the environment, in particular through sensory-motor coordination, information structure is induced in the sensory data, thus leading to perception, learning and categorization.

Principles of morphological computing (physical computing) and data self-organization from biology can be applied in robotics.