Short Course in Biosemiotics

3. The Emergence of Mind

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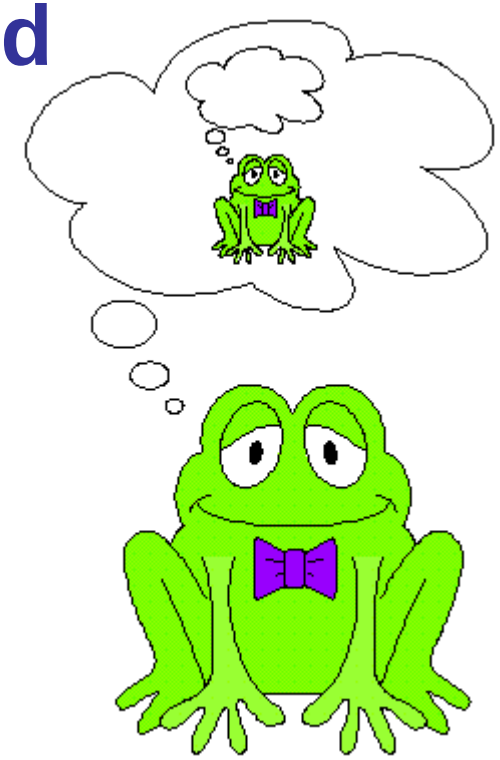
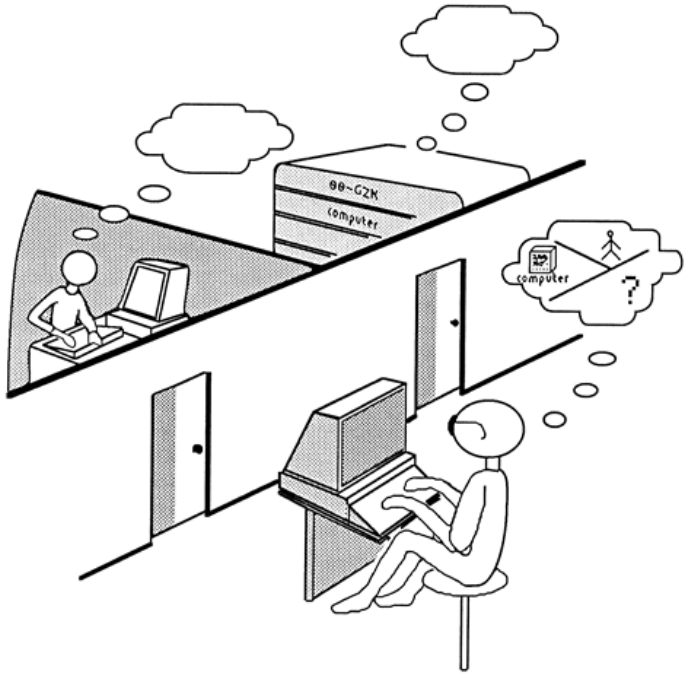


http://www.dailygalaxy.com/my_weblog/2008/06/the-tip-of-the.html

Quest for the “minimal mind”

Alan Turing



Turing test assumes a “human standard” for mind

Computer has to be as smart as a human to pass the test

Is mind a collection of conscious mental functions in humans?

However, this approach tells us nothing about the nature of mind

My approach: look for the **“minimal mind”** that carries only the essential functions of mind

Where to look for the “minimal mind”: in animals, invertebrates, plants, single cells?

Major Evolutionary Transitions

Turchin 1977

1. Life origin: replication & metabolism
2. Active movement
3. Neural control of movement
4. Conditioning and learning
5. Modeling
6. Language
7. Logic and science

Maynard Smith & Szathmary 1995

1. Replicating molecules (e.g., RNA)
2. Replicating molecules in compartments
3. Chromosomes
4. Protein synthesis
5. Eukaryotes
6. Sexual populations
7. Multicellularity
8. Colonies with non-reproductive castes
9. Human society with language

Barbieri 2009

1. Manufacturing/coding semiosis
2. Signaling semiosis
3. Interpretive semiosis

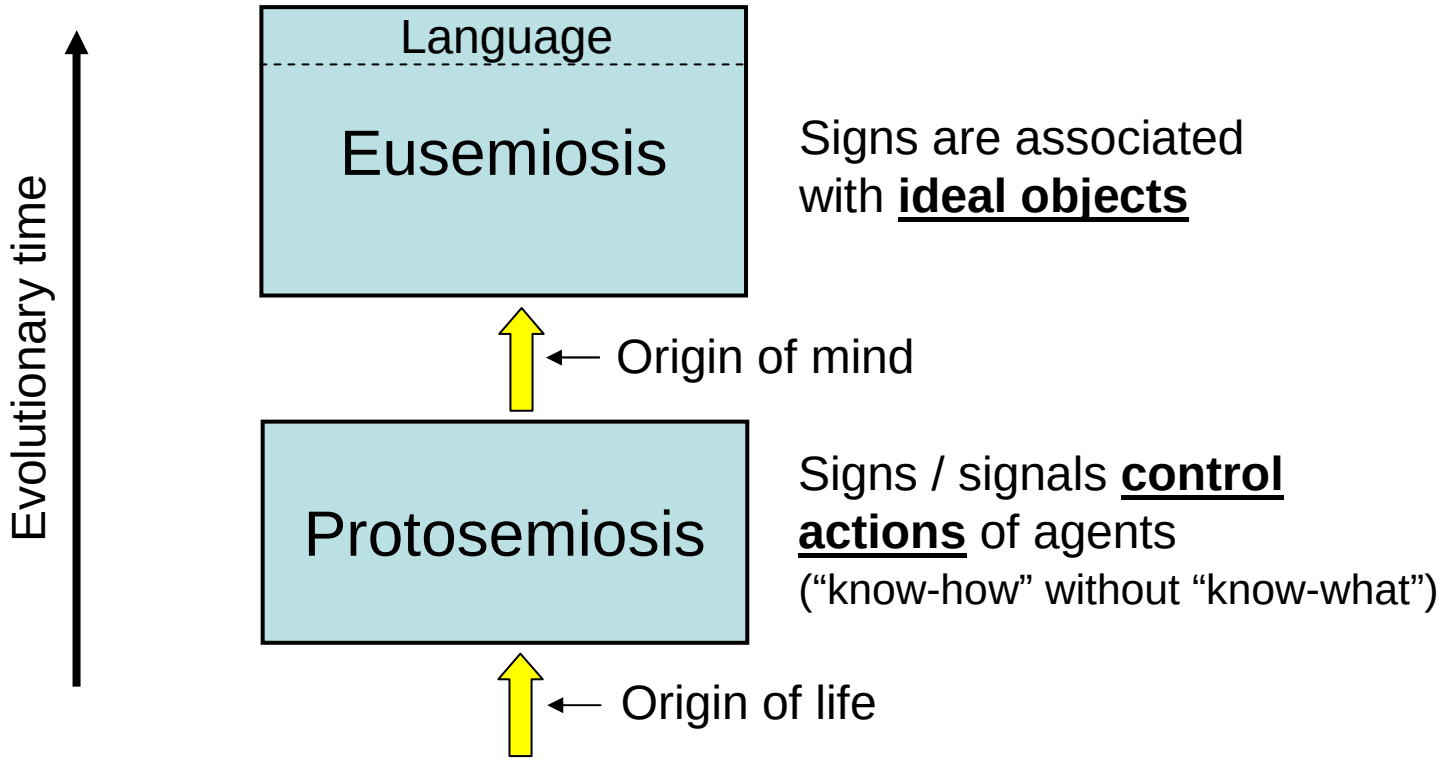
Kull 2009

1. Vegetative semiosis
2. Animal semiosis
3. Cultural semiosis

Where is the origin of **mind**?

Mind marks the transition from protosemiosis to eusemiosis

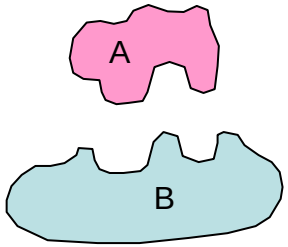
Mind is a tool for classification and modeling of objects



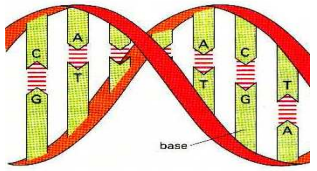
Protosigns in protosemiosis

Protoicons

Specific binding of A to B:



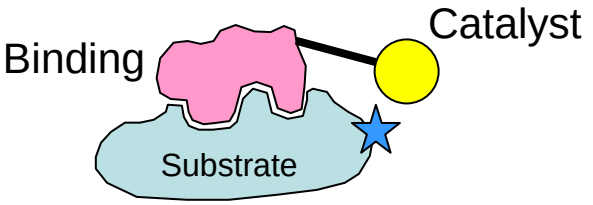
Composite protoicon



Protoindexes

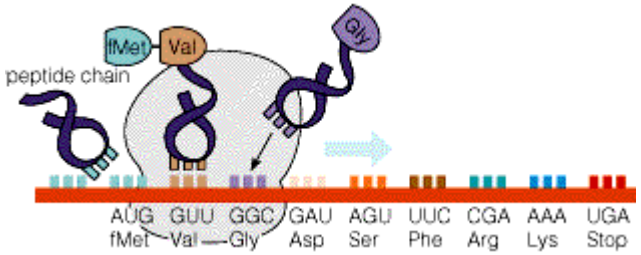
Two functional modules within the same molecule

(e.g., specific catalysts, adaptor molecules)



Protosymbols

Heritable sets of adaptors

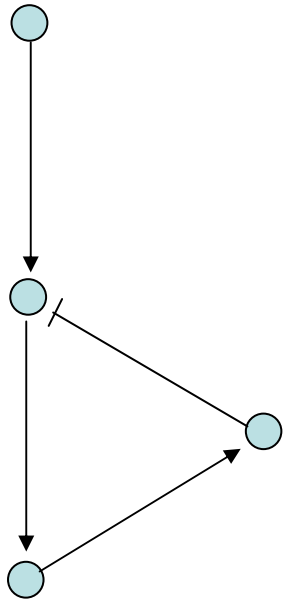


("Natural convention", term of Barbieri, 2003)

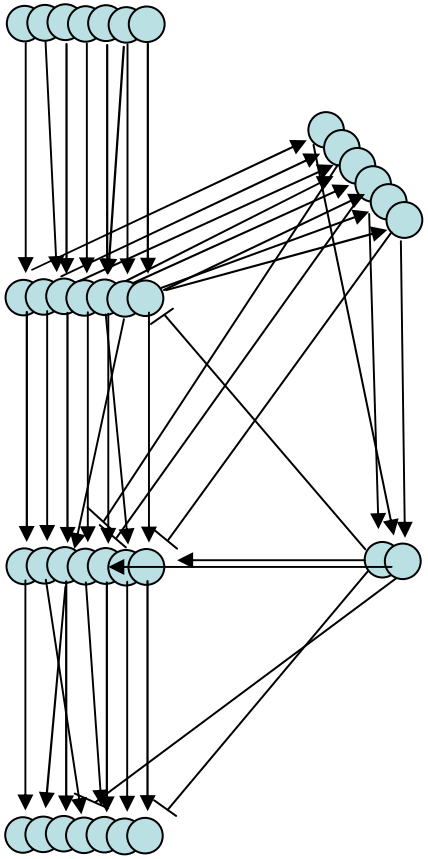
Genetic language = protolanguage

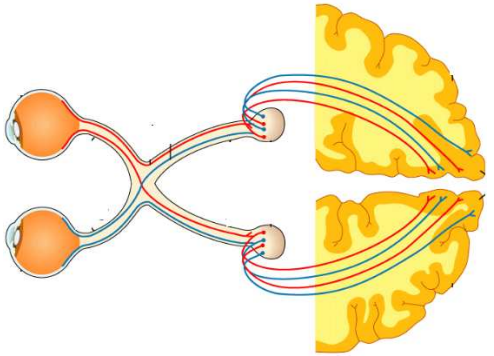
Signaling in protosemiosis and eusemiosis

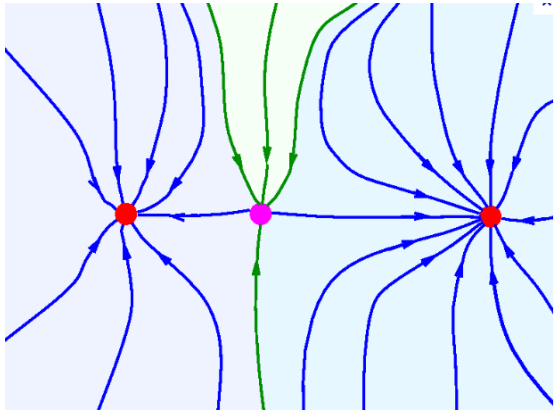
Protosemiotic networks



Eusemiotic networks

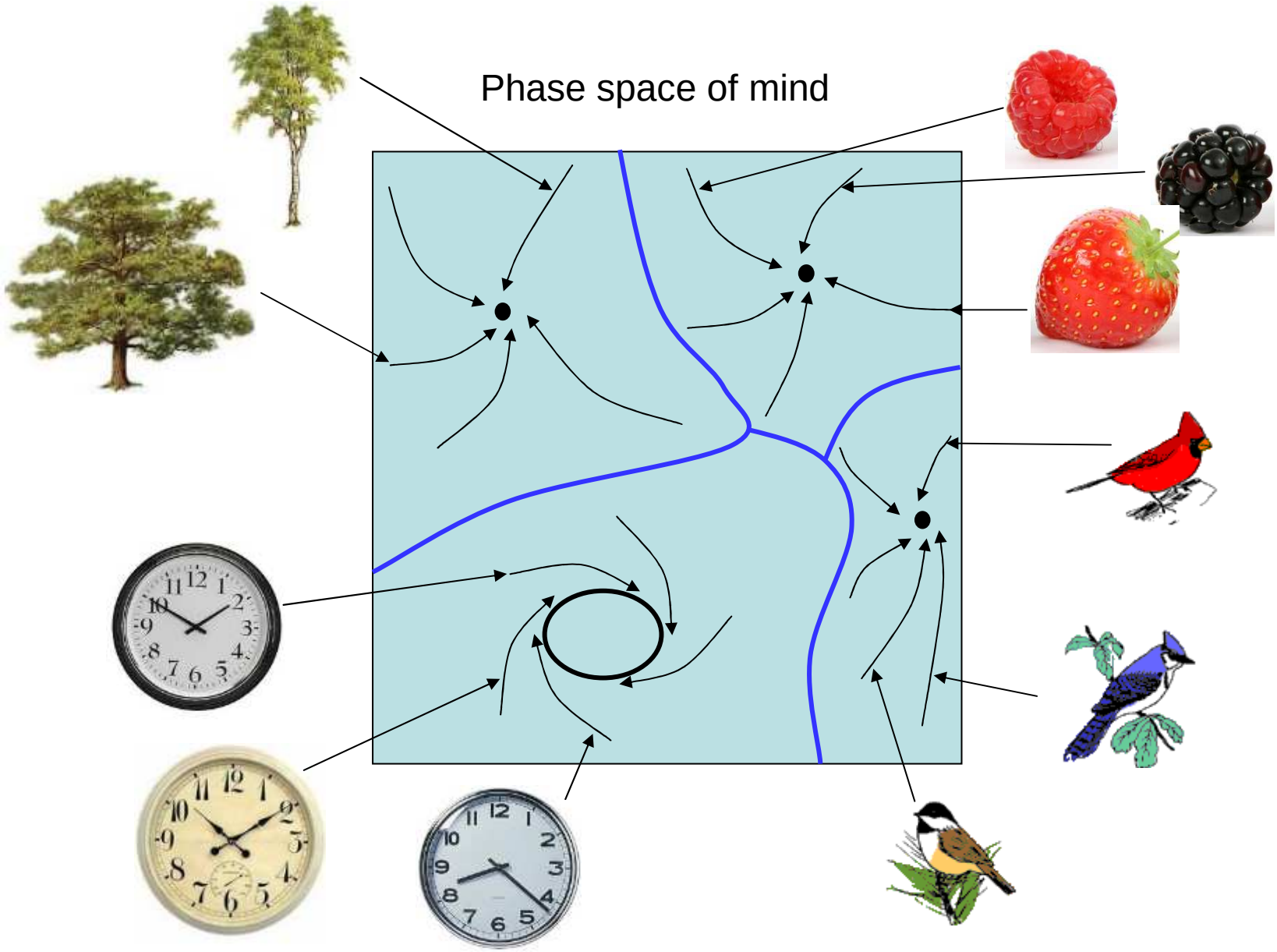






Topology of attractors is more important than specific signaling pathways

Attractors are “ideal objects”



Features of ideal objects

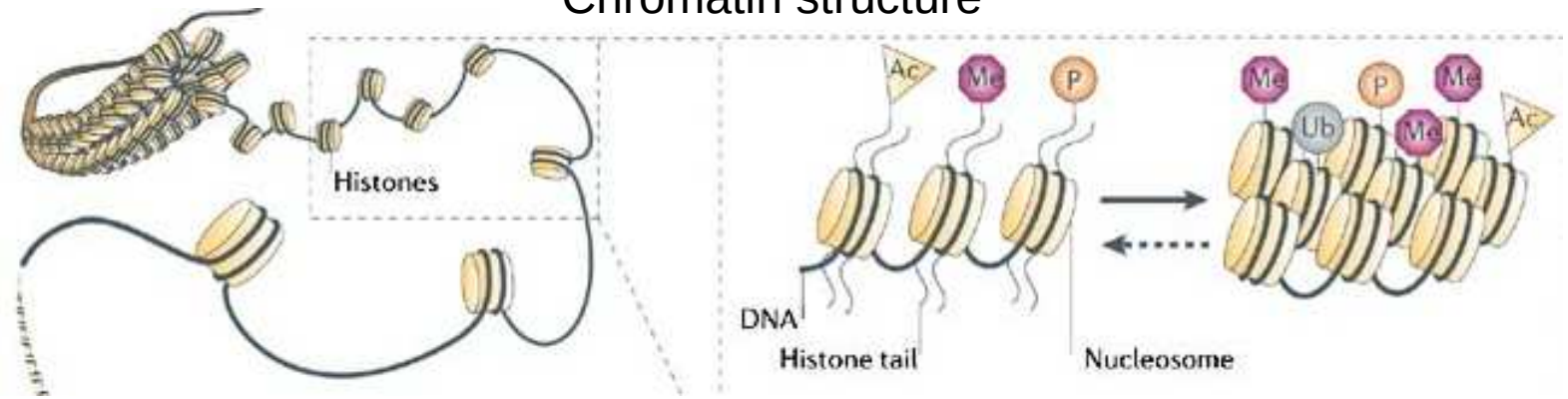
1. Ideal object is a **holistic representation** of an object, i.e. it is not reducible to specific perception pathways
2. Advanced ideal objects are **parametric**: they may include variable and distinguishable features (e.g., color, size)
3. If objects are **tracked by mind**, then classification does not need to be repeated
4. Ideal objects may become **interconnected**, making a semantic web (or thesaurus)
5. Ideal objects can be used for **modeling the environment** via building association between objects or predicting their future states

Epigenetic regulation may have supported the emergence of mind

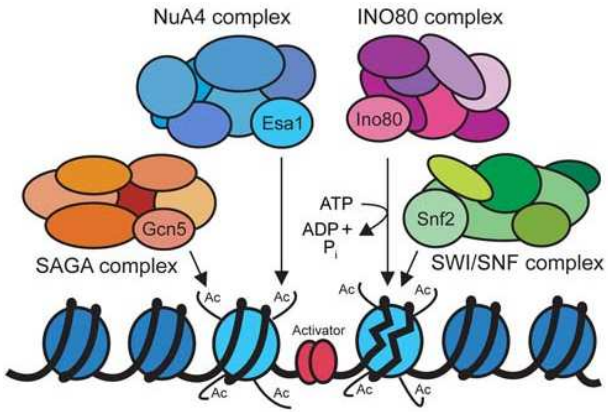
1. Chromatin regulation supports practically unlimited number of attractors
2. Chromatin attractors can be utilized as rewritable memory signs
3. Chromatin attractors can become interconnected via products of co-localized genes.

Epigenetic regulation

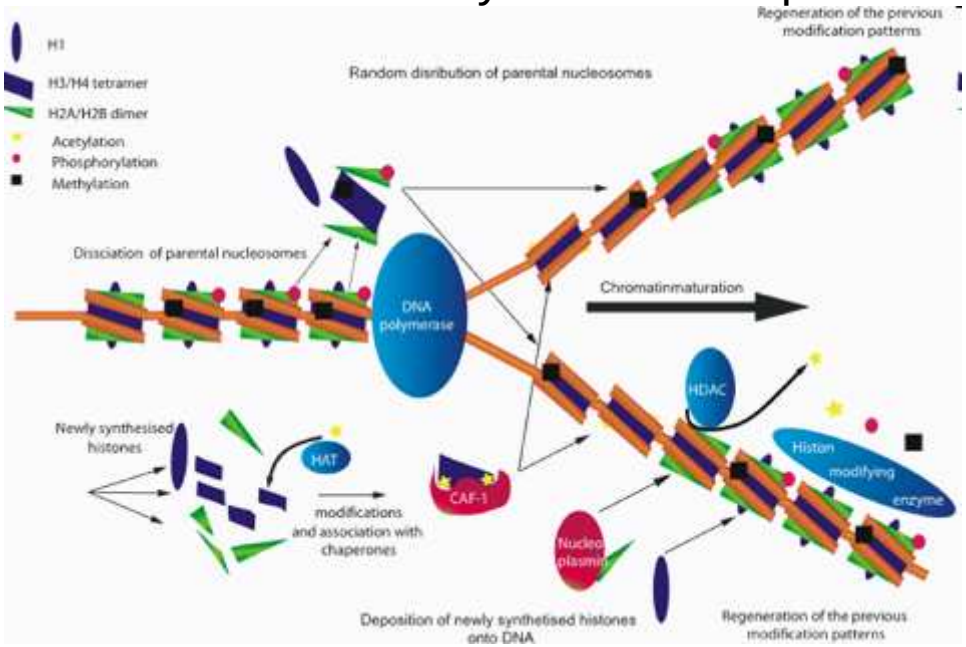
Chromatin structure



Chromatin remodeling agents



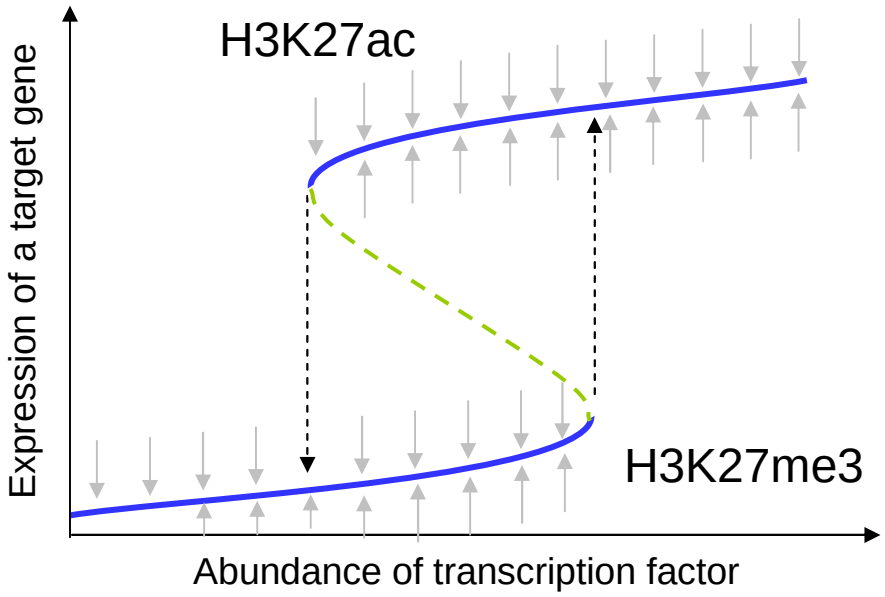
Chromatin reassembly after DNA replication

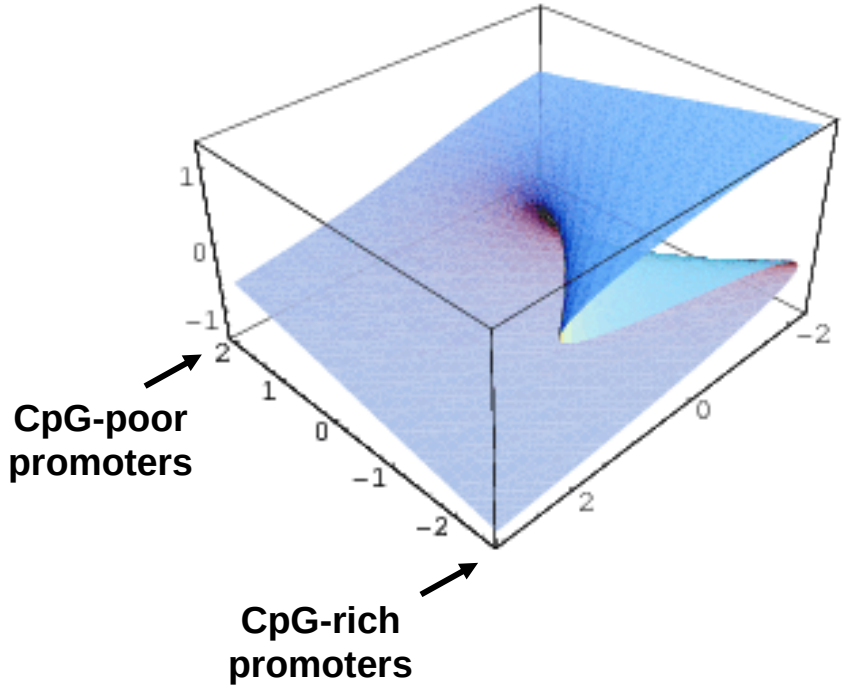


Attractors in local chromatin state

Rene Thom: “Catastrophe Theory”

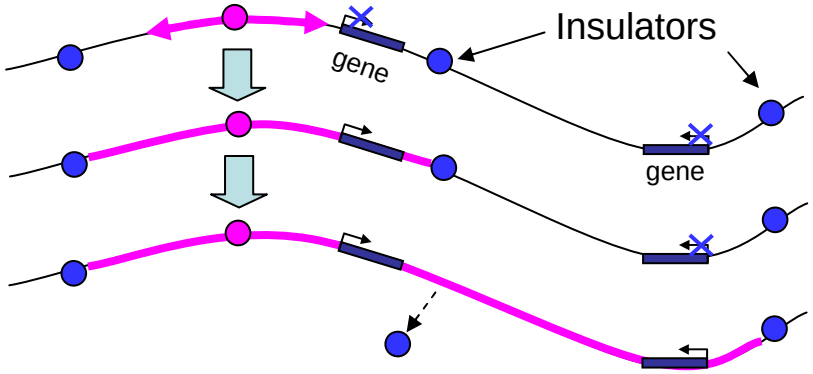
Explains qualitative responses to quantitative changes



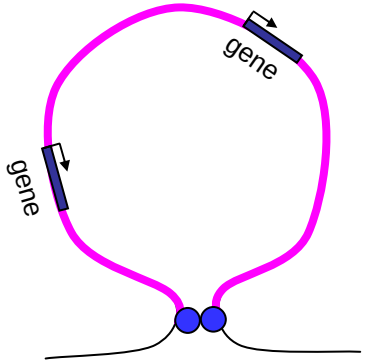


Large-scale epigenetic attractors

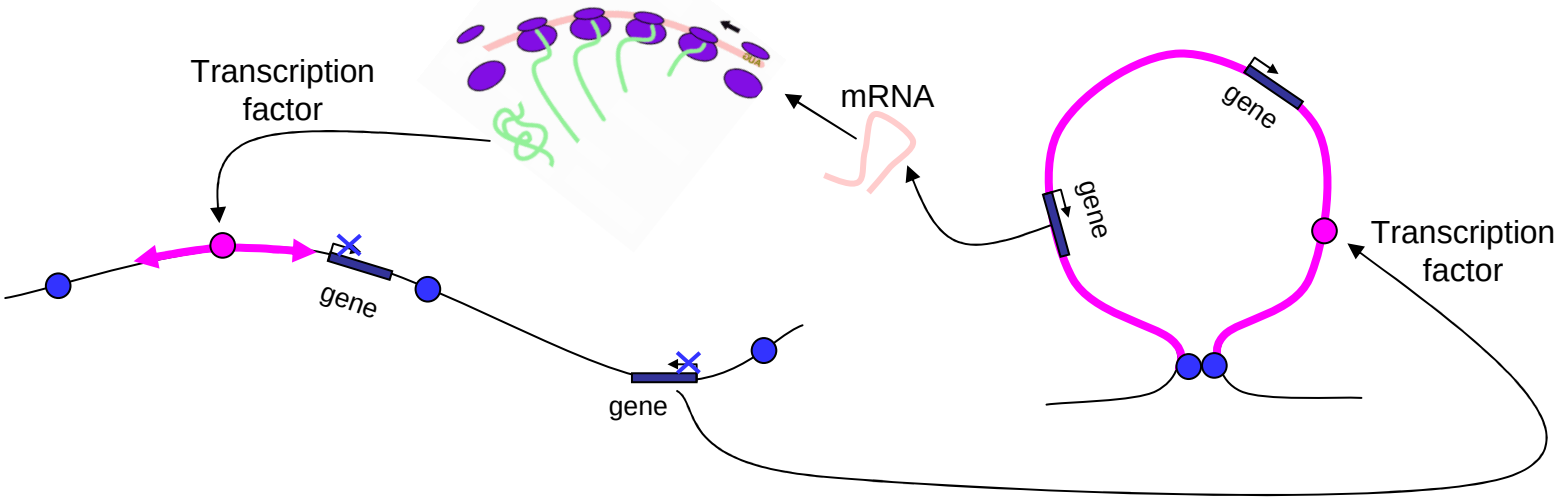
Expanding active or repressed chromatin



Chromatin loops



Functional links between chromatin regions



Increase of mind complexity requires learning

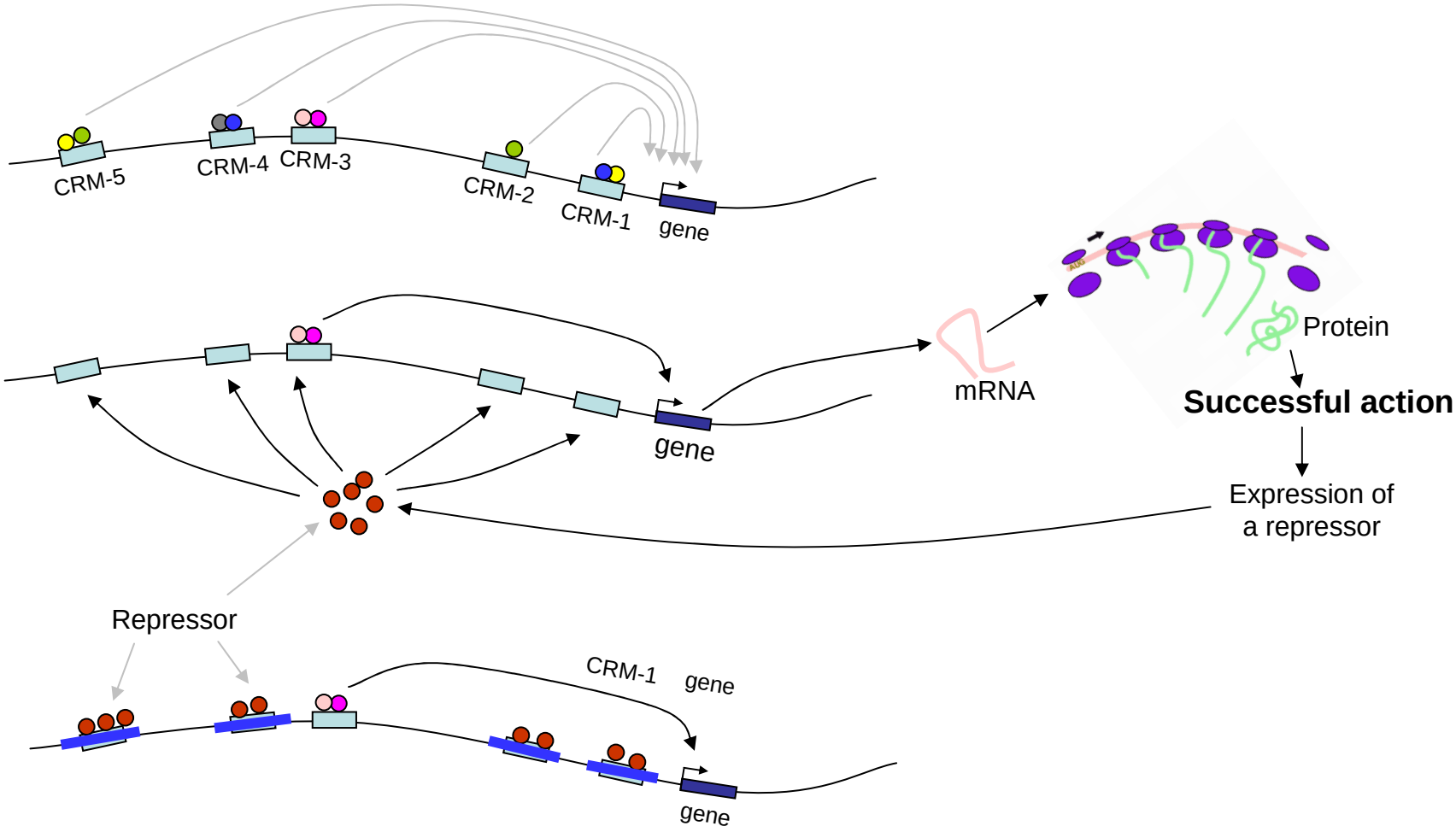
- Mind can function without learning
- Mind complexity (number of ideal objects, links between them, models) cannot increase in the agent without learning
- However limited improvements of minds are possible in lineages of self-reproducing non-learning agents via genetic selection (“evolutionary learning”)

Why “evolutionary learning” is slow and inefficient?

1. Mind is a highly-redundant system with compensations, thus the fitness landscape is almost flat
2. Other mutations that do have a phenotype are likely to be disruptive
3. Genetic selection does not evaluate the performance of mind in individual situations

Cell learning via epigenetic mechanisms

(A toy model)



Nucleus is a “brain” of a cell

First classified object was the body

Why the body is the most likely candidate for the first classified object?

1. Body is the most important object for organism functions
2. Body is monitored by a large number of sensors that provide data for classification
3. Classification of body states allows agents to adjust priorities for their functions (e.g., capturing resources vs. movement, defense, and reproduction)
4. The body is always accessible for agent's actions. Thus, there is no need to develop object-tracking tools.

Modeling functions of mind

Modeling = predicting or anticipating of unperceived

Classification of objects already includes primitive modeling (primary modeling system)

Examples of predictions / anticipations:

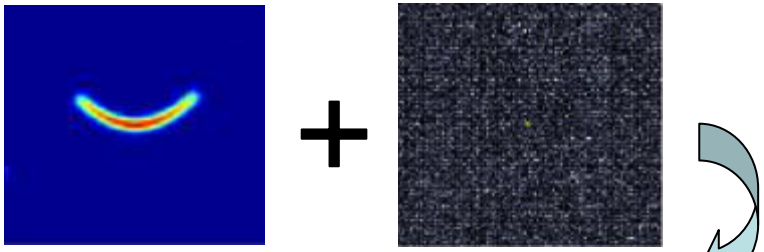
1. Moth finds a host plant and assumes it is suitable for laying eggs
2. Multistep classification:
   (a) Moth finds a candidate host plant by smell
   (b) It lands on the plant and expects to find leaf hairs
   (c) If hairs are absent or have wrong size, then abort
   (d) If hairs are correct, then start laying eggs

Presence of leaf hair is not a separate ideal object for the moth. Instead it is a part of its innate ideal object of the host plant.

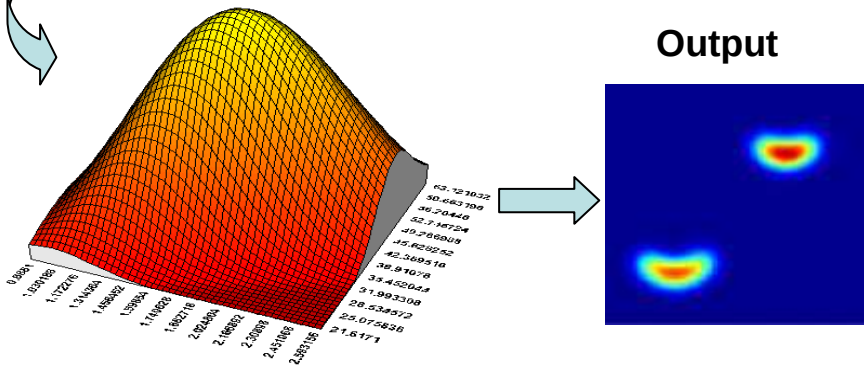
Primary models

"Dynamic Logic" (Perlovsky 2003)

Pattern **Input**

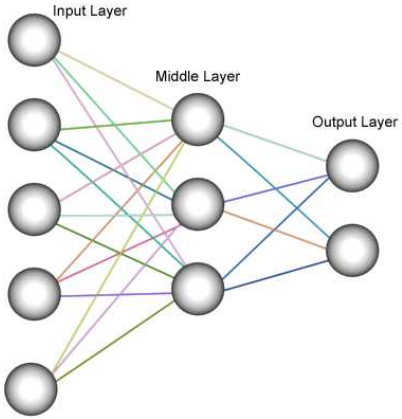


Set of models with parameters +
Set of input data indexed by space, time =>
Likelihood of match =>
Numerical optimization



Output

Neural networks



Multiple layers of pattern-matching

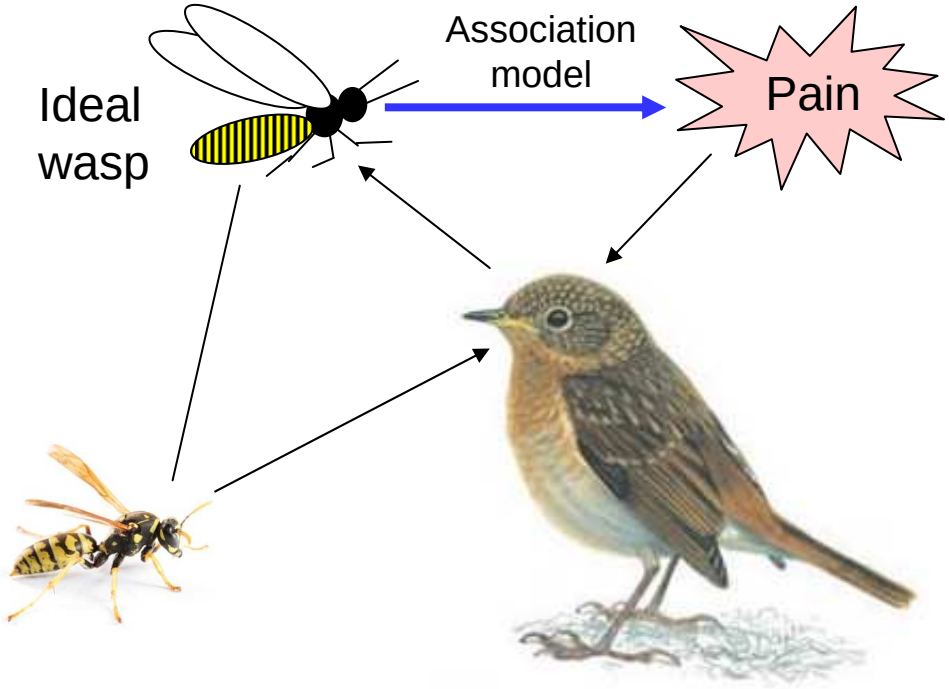
Primary models are icons, according to Peirce's classification of signs

Secondary Modeling System

(Term from Yuri Lotman and Thomas Sebeok)

In the primary modeling system, ideal objects are not connected

In the secondary modeling system, ideal objects are connected via arbitrarily established links



Types of ideal objects:

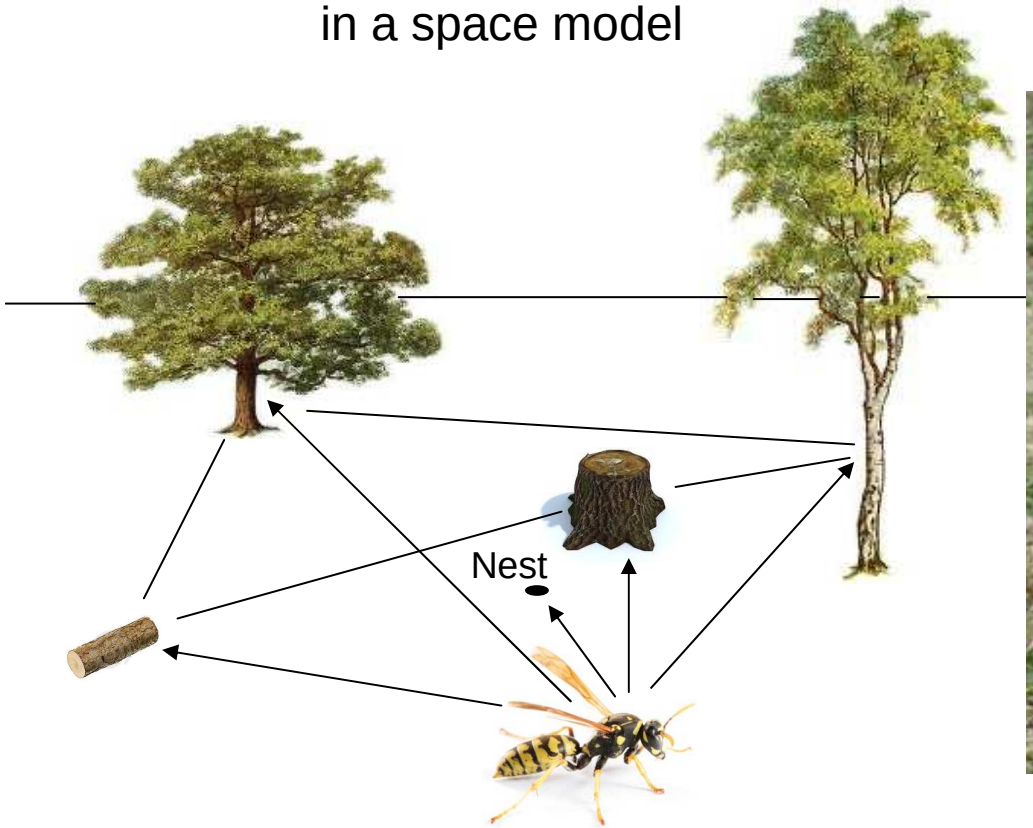
1. Individual objects
2. Natural class of objects
3. Set of objects
4. Feature of objects
5. Feelings
6. Goals, motivations
7. Actions

All these ideal objects can be connected into a network

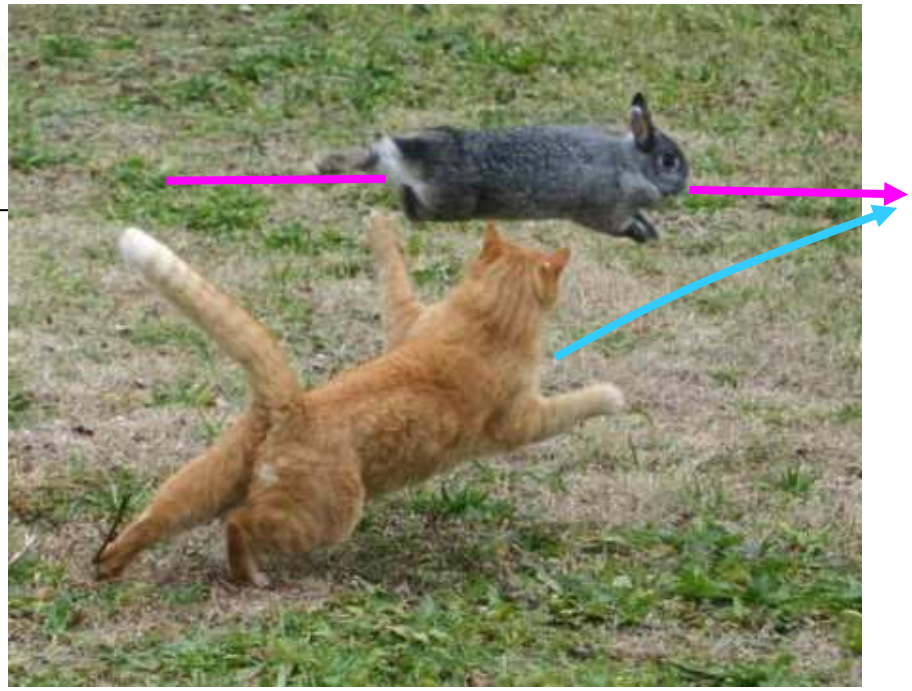
Secondary Modeling System

Other kinds of models

Individual objects combined in a space model

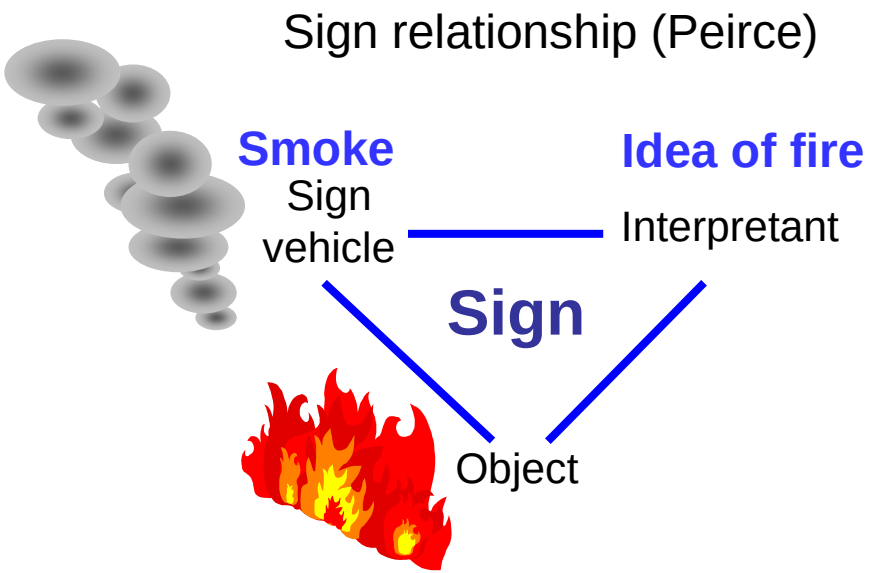


Dynamic models



From: http://playingwithmodels.wordpress.com

Secondary models are indexes



Peirce viewed sign relationship as a component of the world rather than model developed by agents

(objective idealism)

Objective idealism leads to dogmatism as models become over-trusted.

Models may fail to generate reproducible results and need to be tested.

Model relationship

(Relationship between the model and reality)

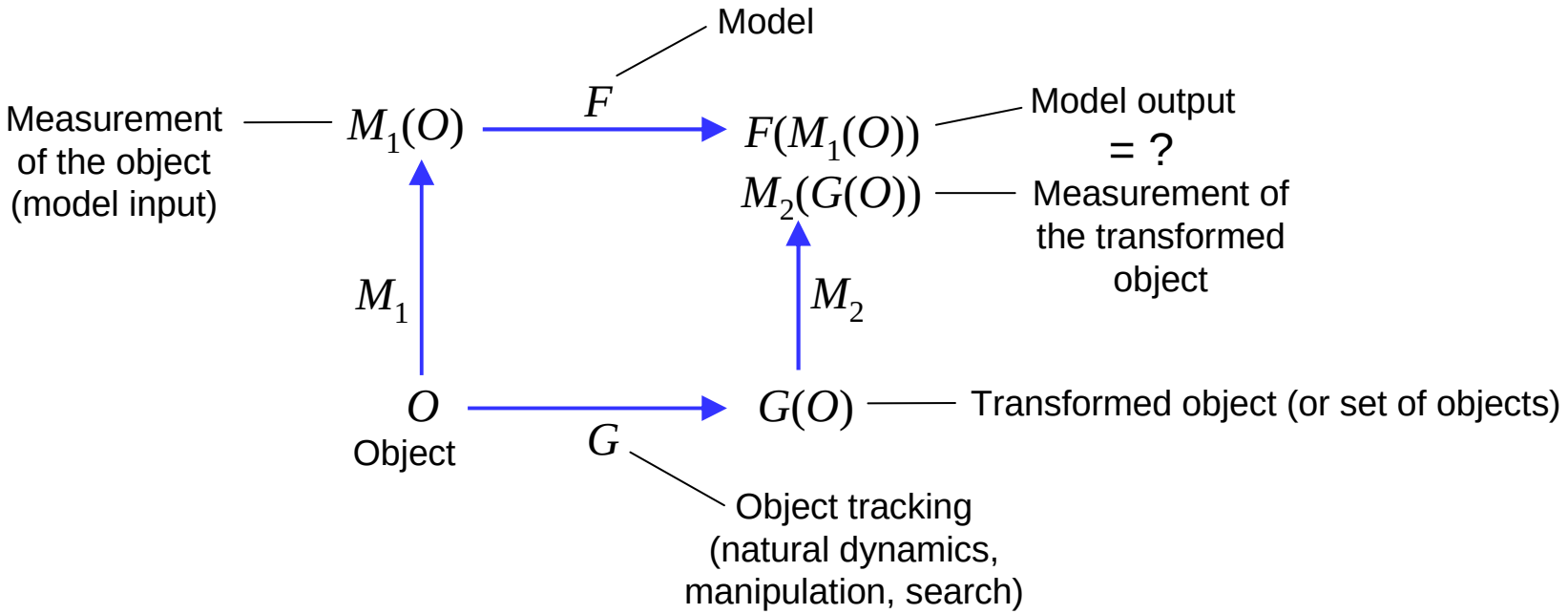


Diagram is commuting if $F(M_1(O)) = M_2(G(O))$ [eq. 1]

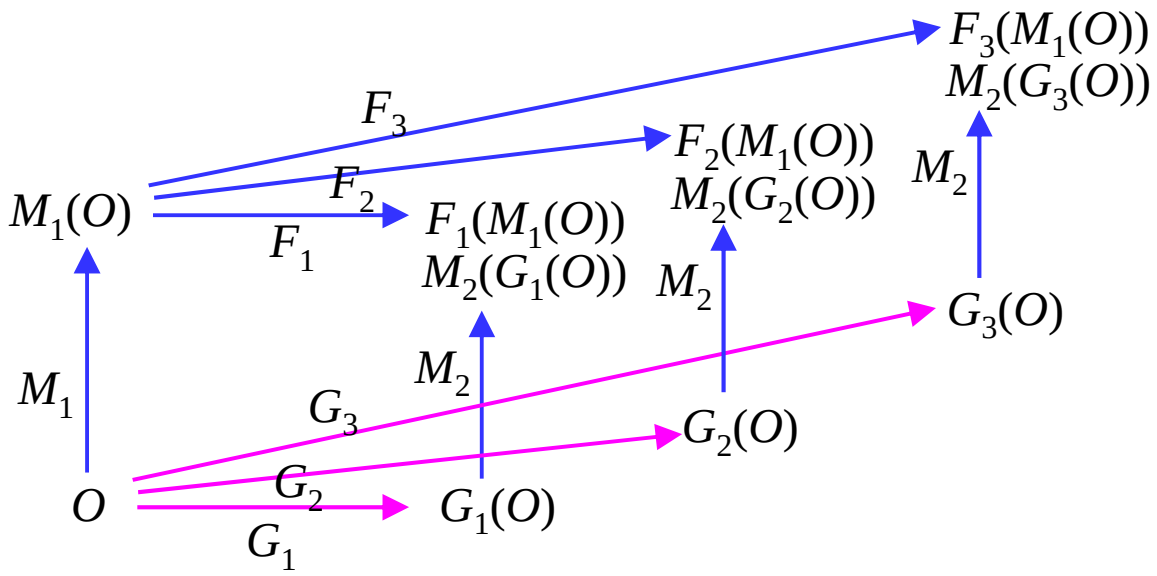
Model relationship (F, G, M_1 ,M_1) is universal if the diagram is commuting for every object O.

Model flavors: (a) probabilistic model (i.e., $F(M_1(O))$ is a probability distribution)
(b) association model (i.e., $G(O)$ is a set, where some object satisfies eq. 1)
(c) manipulation model

Meta-model for multiple manipulations

Set of manipulations: (G_1, G_2, G_3)

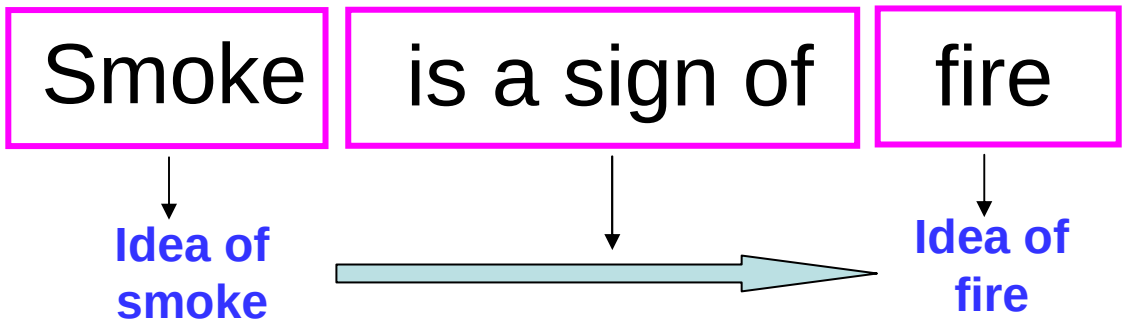
Set of models: (F_1, F_2, F_3)



Language is a tertiary modeling system

Efficient communication of models is possible only by language
(= cultural semiosis, according to Kull 2009)

In language, signs emulate the structure of models



Words of language are symbols because their meaning is established by convention in the communication system

Thus, tertiary communication system is based on symbols

What is the role of mind in embryo development?

Traditional approach:
Embryo development is a programmed deterministic process

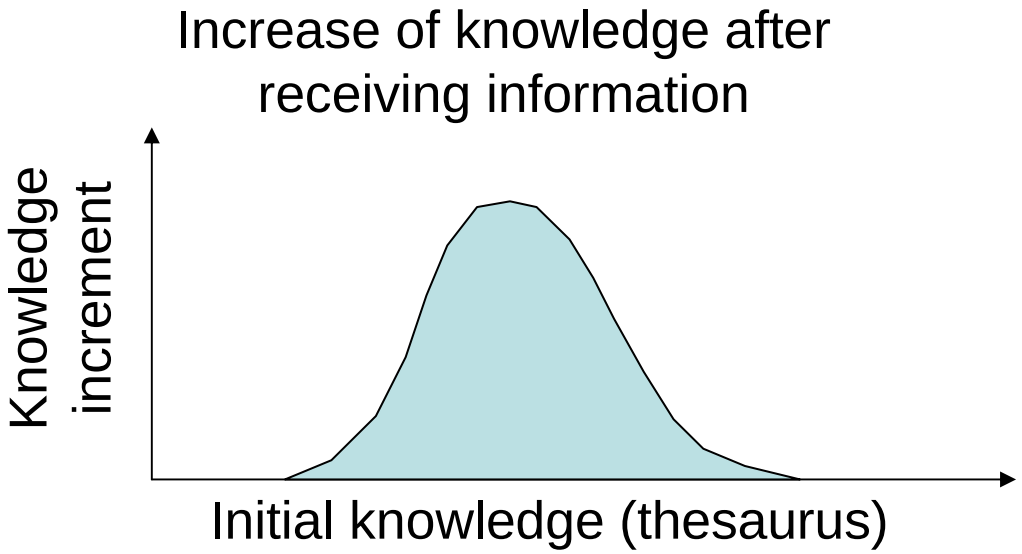
Alternative approach:
Embryo development involves classification and learning at the cell level

Cells attempt to find a “job” in the body that fits to available functional niches and cell’s pre-history. If a job is not found, then the cell goes into apoptosis.

Neurons establish functional feedback regulation of growing organs, where non-functional cells or cell parts (e.g., synapses) are eliminated (Edelman 1988)

Semantic theory of information

Julius Schreider



Metainformation = knowledge which is needed to interpret (understand) information

Consequences:

1. Knowledge is not universal
2. Knowledge may be not accessible

The notion of metainformation contradicts to the traditional epistemology

Knowledge:
1. Is not universal
2. Is not accessible to every agent

Knowledge is not perceived without metainformation and there is no sure trajectory of learning which will generate necessary metainformation

Relativistic epistemology

The same meadow and grass are perceived and used differently by a cow and ant

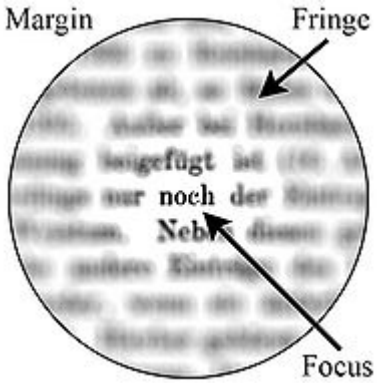
Relativistic epistemology is not subjective idealism

The world is real but its representations and models are different for each communication system

Representations of the world are not random but **optimized in evolution**. They satisfy criteria of **utility** (support of functions) and **logical consistency** (logic is needed for adaptability)

Mind and attention

Attention = focusing on one aspect while ignoring others



William James described attention as having a **focus**, a **margin**, and a **fringe**

Protosemiotic level: Attention = priority of one function
Eusemiotic level: Focus on the ideal object

Attention can be reset exogenously or endogenously

Mind and free will

Protosemiotic level: Free will = useful variation

In general, variations are detrimental for agents because they disrupt functions. However, at a certain level of complexity, agents can compensate bad consequences of variations. Then variations in behavior (e.g., random walk) become useful as they allow agents to discover new resources and functions.

Eusemiotic level: Free will = spontaneous selection of ideal objects

Agents with mind can select ideal objects (e.g., goals) spontaneously, and follow them.

Modeling capacity can further improve the free will because agents can evaluate their options before they act

Mind and consciousness

Consciousness is eusemiotic activity and requires mind

Conscious mind:	Unconscious mind:
Focused	Diffuse
Personal	Impersonal
Executive	Emotional
Proactive	Reactive

Conclusions

1. Mind is a tool for classification and modeling of objects
2. Origin of mind = transition from protosemiosis to eusemiosis
3. The hallmark of mind is a holistic perception of objects
4. Classification capacity of mind may have originated from the ability of organisms to classify states of their own body
5. Modeling capacity of mind include primary models based on a single ideal object, secondary models that connect different ideal objects, and tertiary models designed for communication via language
6. Model testing is a commuting relationship that includes object measurement and tracking
7. Precursors of free will and attention exist at the protosemiotic level, but consciousness has eusemiotic nature