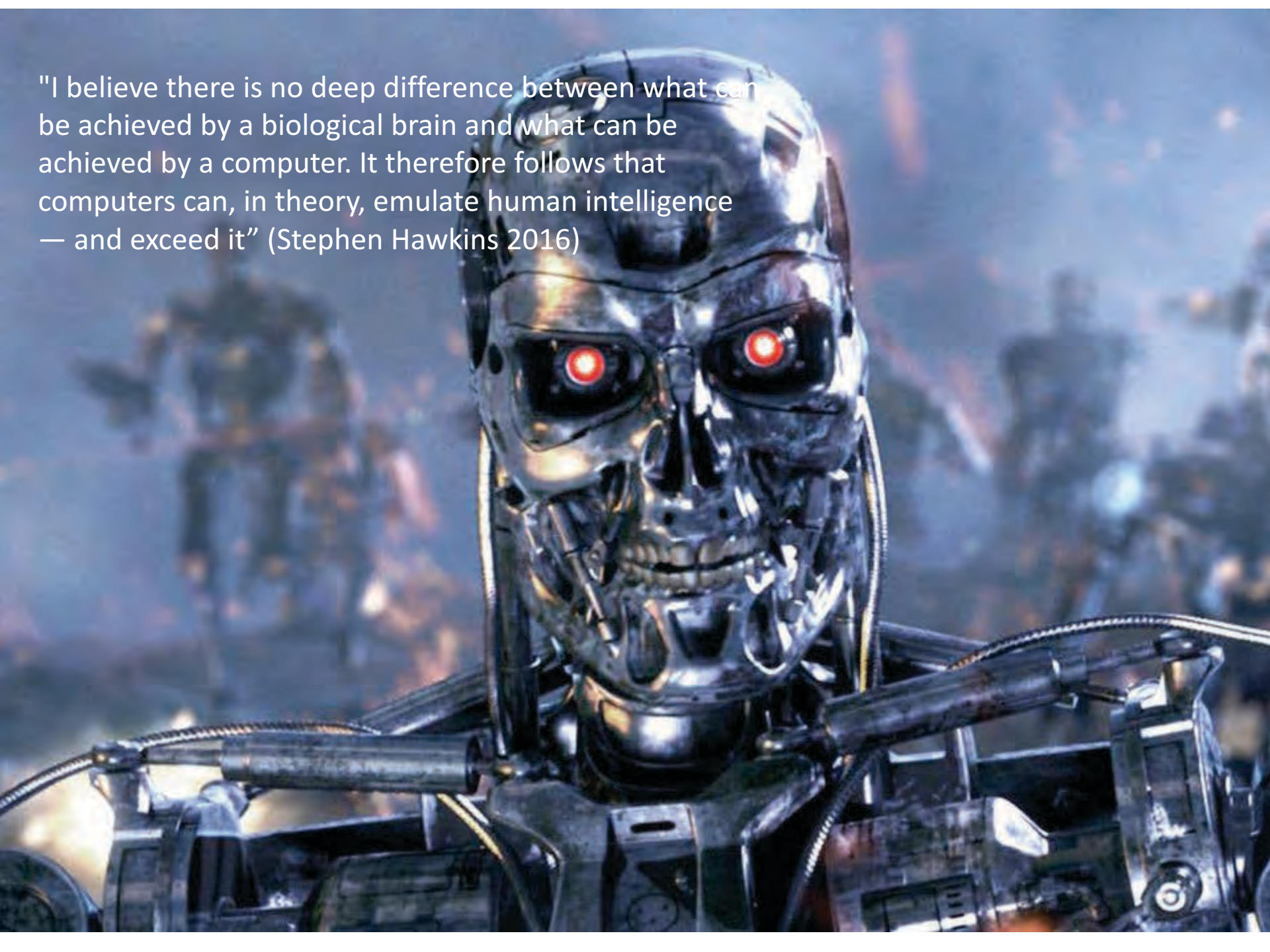


Embodied Cognition (or a Biological Theory of Knowledge)

Rodrigo Suárez

"I believe there is no deep difference between what can be achieved by a biological brain and what can be achieved by a computer. It therefore follows that computers can, in theory, emulate human intelligence — and exceed it" (Stephen Hawkins 2016)

"I believe there is no deep difference between what can be achieved by a biological brain and what can be achieved by a computer. It therefore follows that computers can, in theory, emulate human intelligence — and exceed it" (Stephen Hawkins 2016)



Talos of Crete: The bronze automaton



Moravec's paradox

"it is comparatively easy to make computers exhibit adult level performance on intelligence tests or playing checkers, and difficult or impossible to give them the skills of a one-year-old when it comes to perception and mobility."

Brooks argued that in order for robots to accomplish everyday tasks in an environment shared by humans, their higher cognitive abilities, including abstract thinking emulated by symbolic reasoning, need to be based on the primarily sensory-motor coupling (action) with the environment, complemented by the proprioceptive sense which is a key component in hand–eye coordination.



Rodney Brooks (1954 -)

Nouvelle AI; situated cognition; enaction; biology of cognition

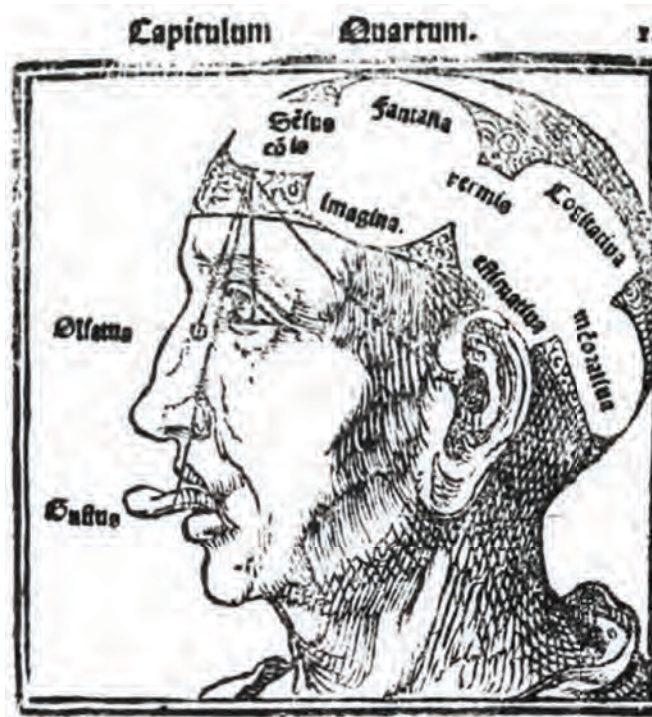




Aristotle (384-322 BC)

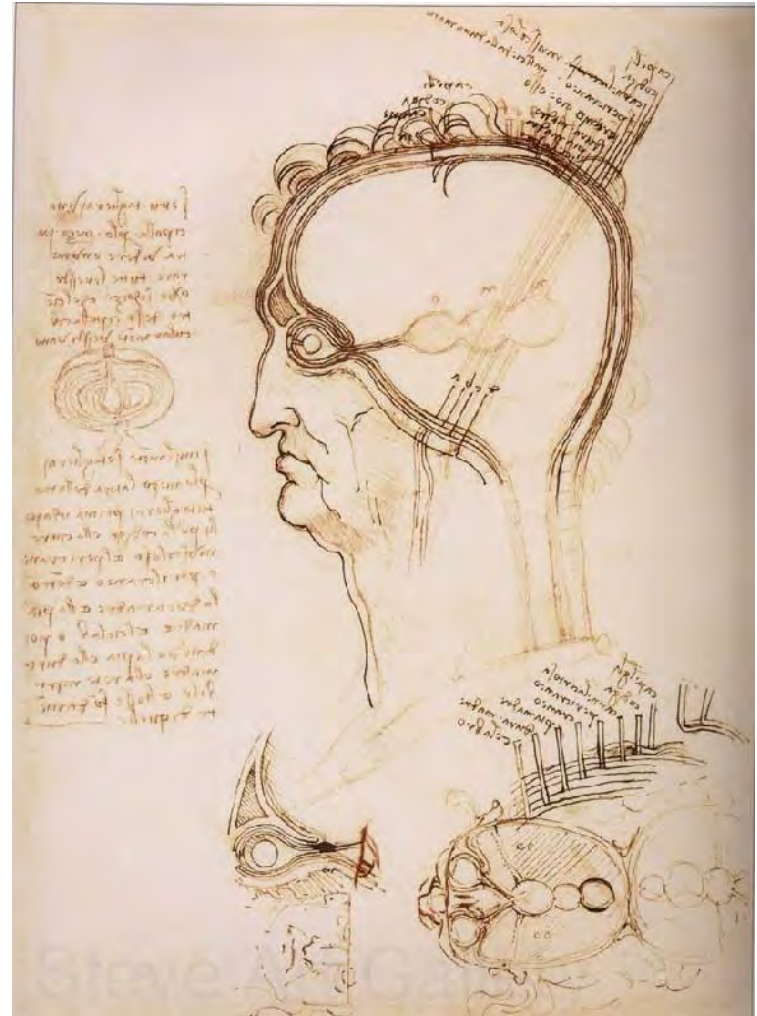
- Epigenesis to replace preformism
- Holism (the whole is of necessity prior to the part)
- Matter and 'formal cause' are complementary and interdependent.
- Mind (anima, soul, form, essence, psyche) and body are not distinct, and are present in all living organisms... although human intellect may exist independently.
- The heart moves vital fluids, the brain is just a coolant.

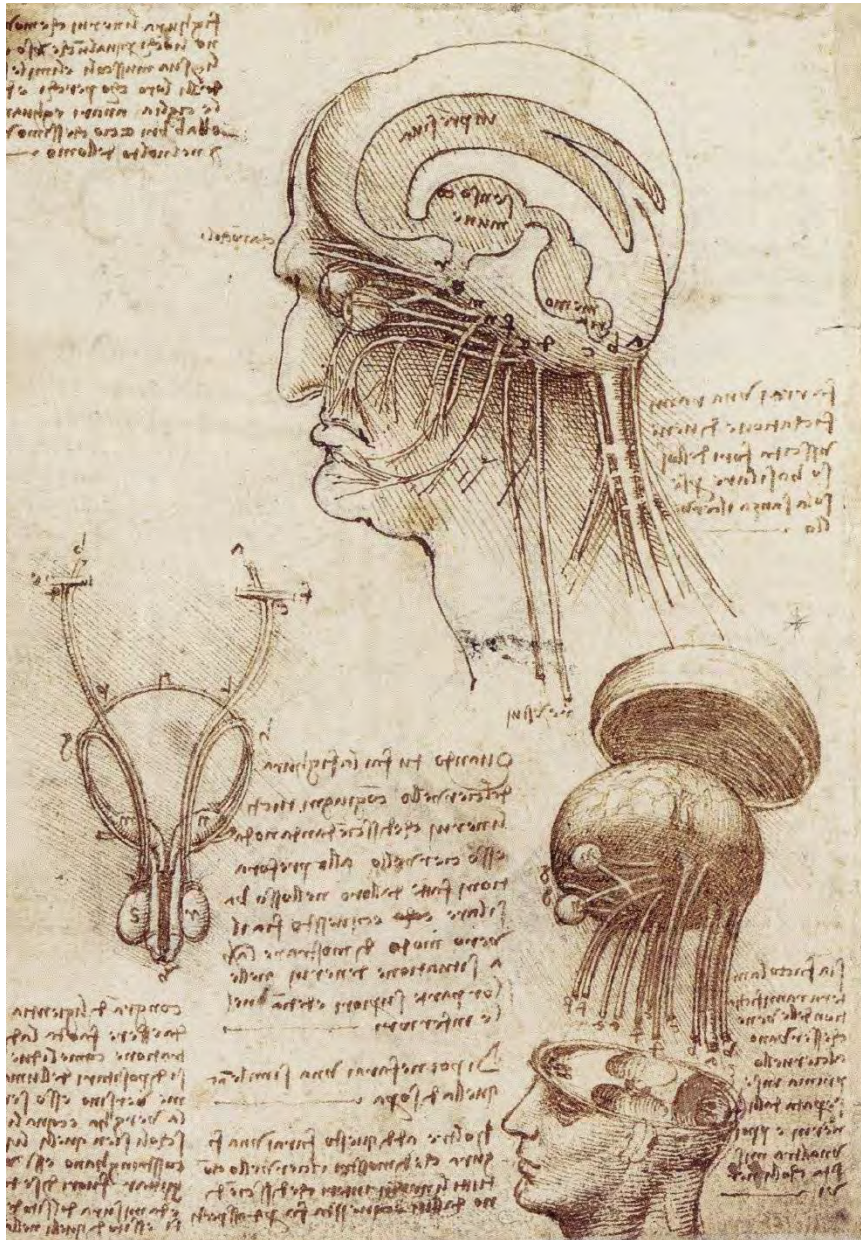
Galen (129-210 AD)



- Humours (spirits) travel within hollow nerves, arteries and veins.
- These spirits underwent refinement at each stage, from appetitive in the liver to vital in the heart and animal in the brain, ensuring a continuum between perception, sensation, and thought.
- Humoural system was embodied.

Leonardo da Vinci (1452-1519)



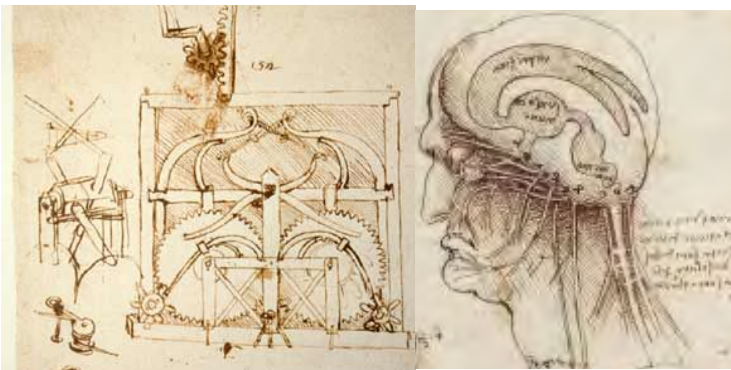
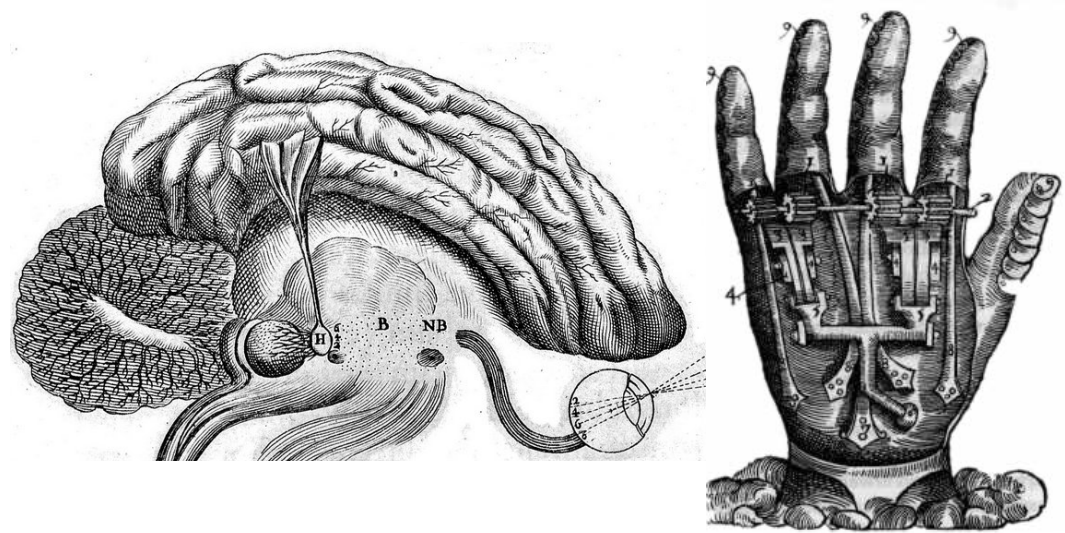






- Machine-like mechanisms rule the body (like automata), there's no formal causes.
- The Soul, however, is not open to mechanistic explanation, as it is not made of matter (*Cartesian dualism*).
- The Pineal gland is the interface between body and soul.

René Descartes (1596-1650)
Discourse on the Method (1637)
Meditations on First Philosophy (1641)
Principles of Philosophy (1644)



“cogito, ergo sum” as a response to radical skepticism



Julien Offray de La Mettrie (1709-1751)

A strong determinists/materialists of the 18th century
French enlightenment

- From animals to man there is no abrupt transition.
- Explicitly denied the existence of God, as logically implausible.
- Mental processes arise from material interactions, and depend on bodily actions.
- Rejected Cartesian body-mind dualism.
- Hedonistic pursuit, died of gluttony-induced gastritis, followed by delirium...
 'further demonstrating the bodily effects on the mind'

The Natural History of the Soul (1745)

L'homme Machine (1747)



Immanuel Kant (1724-1804)

- Experience is a 'construction' of the mind.
- Introduction of 'subjective' views, such as 'a priori' experience, in perception.
- An active role of the individual.
- The soul is not separate from the body

Critique of Pure Reason, 1781

Critique of Practical reason, 1788

Critique of judgement. 1790



Johann Wolfgang von Goethe, 1749-1832

Theory of Colours, 1810; perception, colour
opponent wheel

Opposed to Newton's analytic treatment of
colour.

Early versions of Gestalt Psychology
(Phenomenology, subjectivity)

Early versions of biological homology
(Transformation of plants 1790)

Jean-Baptiste Lamarck (1744-1829)



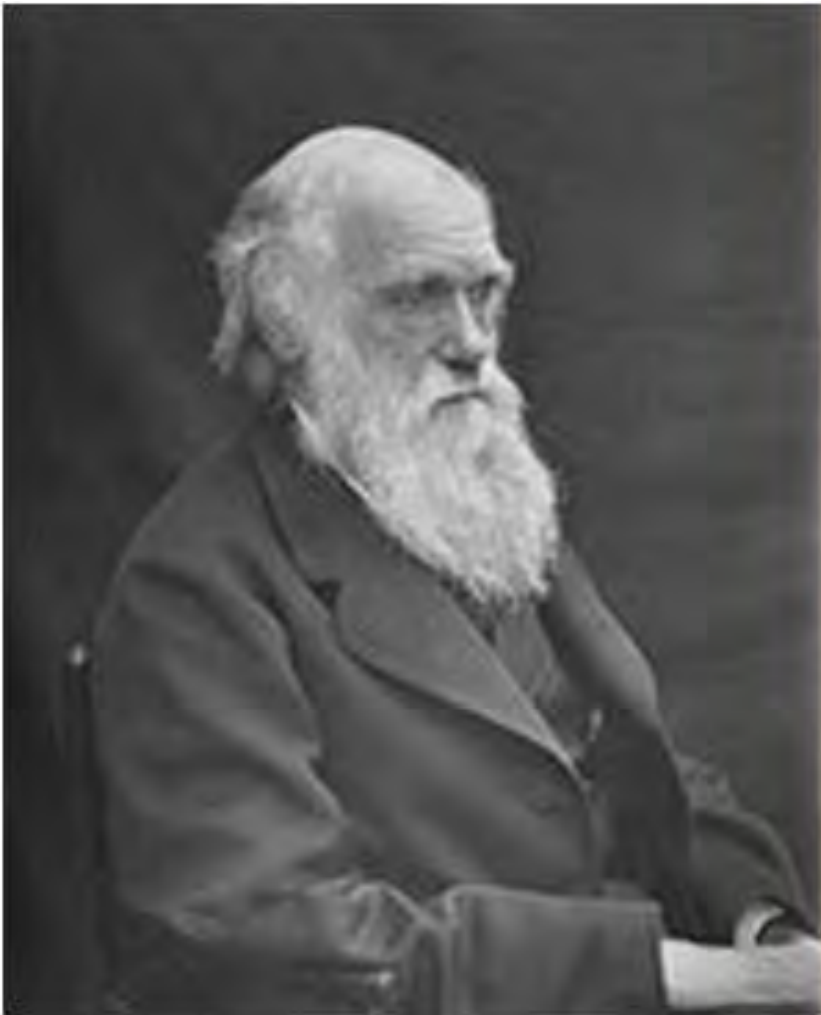
Zoological Philosophy (1809):

- Common ancestry
- Use and disuse
- Epigenesis
- Common 'life faculties':
 - Feeding
 - Building themselves
 - Development
 - Reproduction

Physical causes, feeling is embodied and ego indivisible.

From the foregoing principles I think we may conclude :

1. That the phenomenon of feeling is not more miraculous than any other phenomenon in nature, that is, any phenomenon produced by physical causes ;
2. That it is not true that any part of a living body, or any substance composing it, has in itself the faculty of feeling ;
3. That feeling is the result of an action and reaction, which become general throughout the nervous system, and are performed with rapidity by a very simple mechanism ;
4. That the general effect of this action and reaction is necessarily felt by the individual's indivisible ego, and not by any separate part of his body ; so that it is only by illusion that he thinks that the effect is entirely wrought at the point where the impression was received ;



THE
DESCENT OF MAN,
AND
SELECTION IN RELATION TO SEX.
BY
CHARLES DARWIN, M. A., F. R. S., ETC.

1871

'Umwelt' and the School of Bio-semiotics

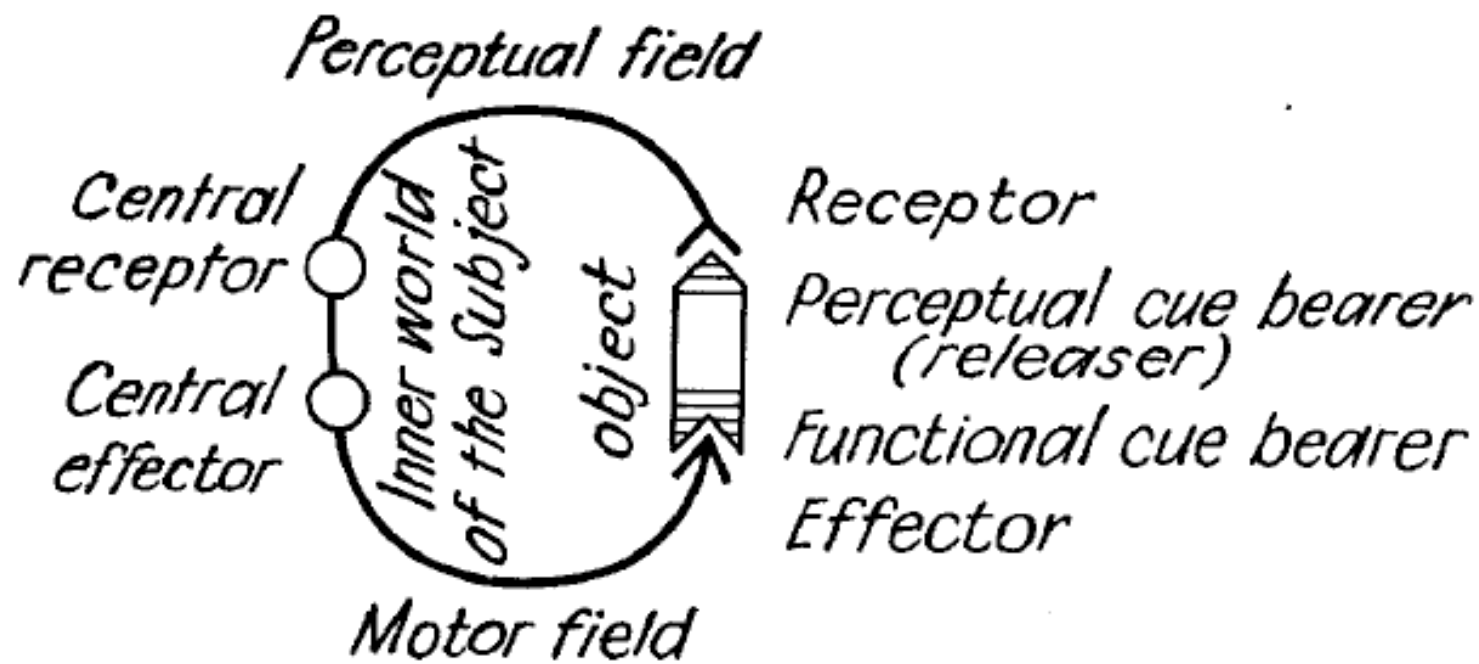


A Stroll Through the Worlds of Animals and Men

A Picture Book of Invisible Worlds¹

JAKOB VON UEXKÜLL (1934)

Jakob von Uexküll (1864-1944)



Umwelt: "self-centered world"

It is also the semiotic world of the organism, including all the meaningful aspects of the world for any particular organism...

An organism creates and reshapes its own *umwelt* when it interacts with the world.

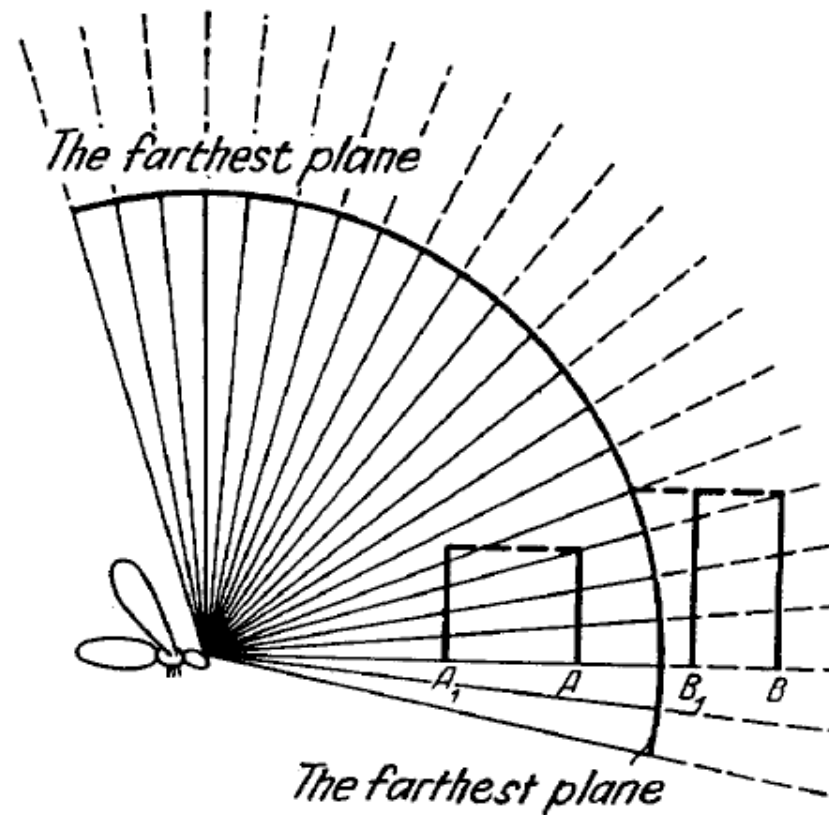


FIG. 8

The visual space of an insect in flight

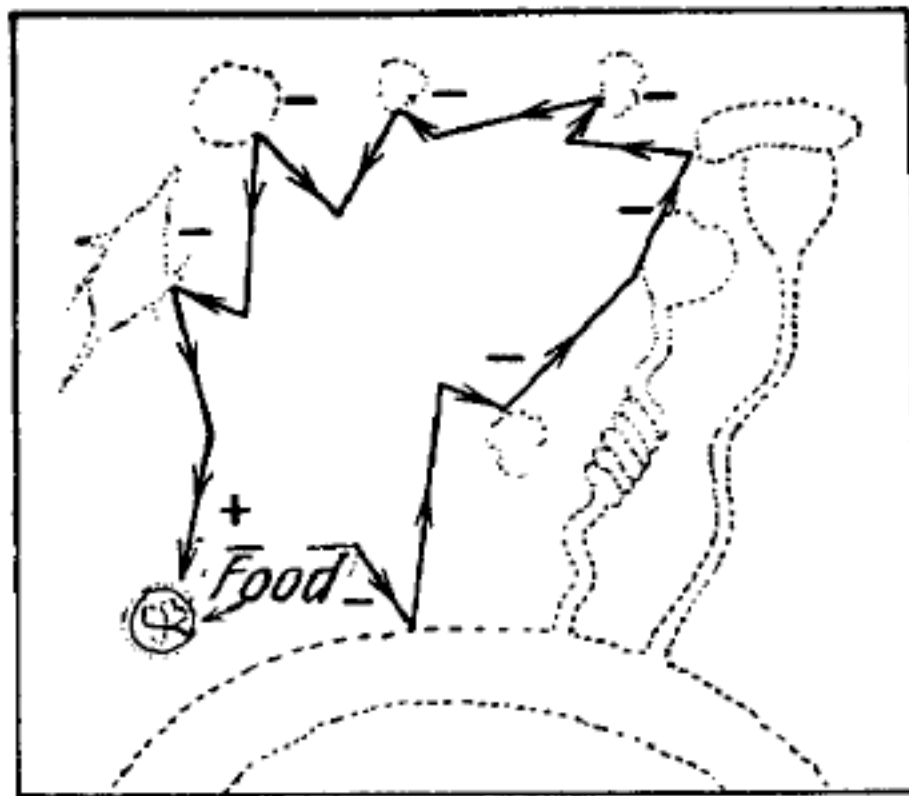
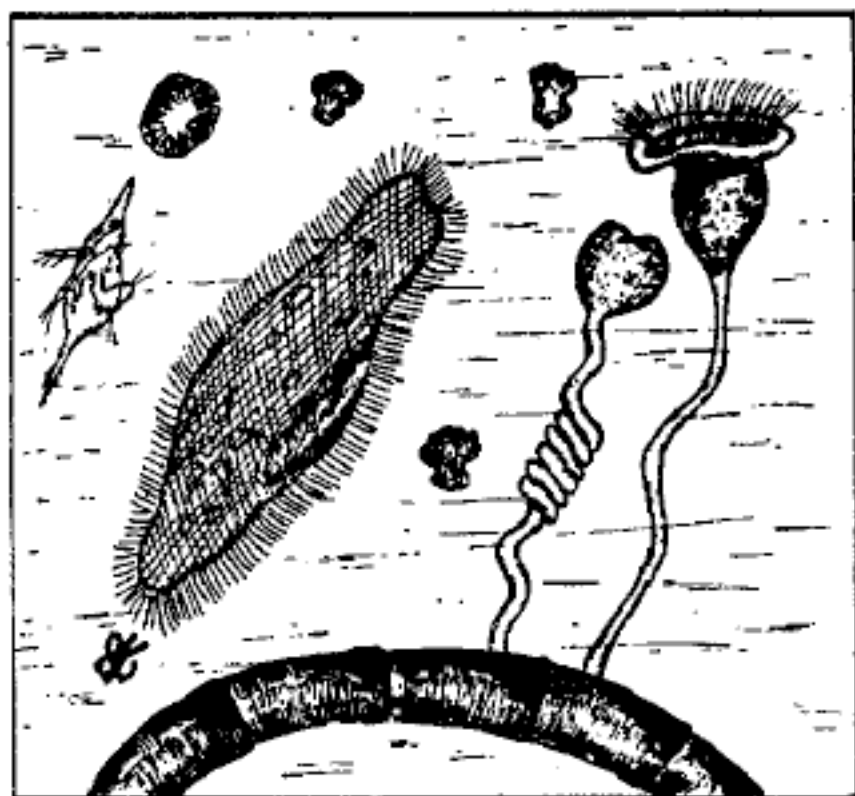


FIG. 15

Environment and *Umwelt* of the *Paramecium*

School of Vienna (1930-50s, Ludwig von Bertalanffy & Paul Weiss)



Paul Weiss 1898-1989



Ludwig von Bertalanffy 1901-1972

School of Vienna (1930-50s, Ludwig von Bertalanffy & Paul Weiss)

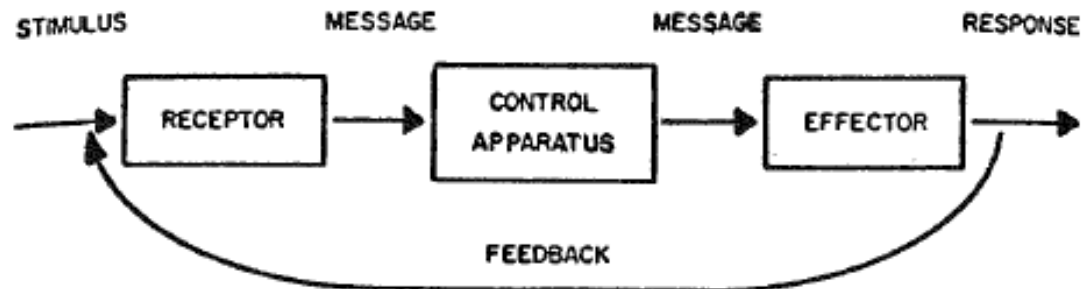
General System Theory

Foundations, Development, Applications



by Ludwig von Bertalanffy 1968

1901-1972



Hierarchically Organized Systems



Paul Weiss (1898-1989)

PhD advisor of Roger Sperry

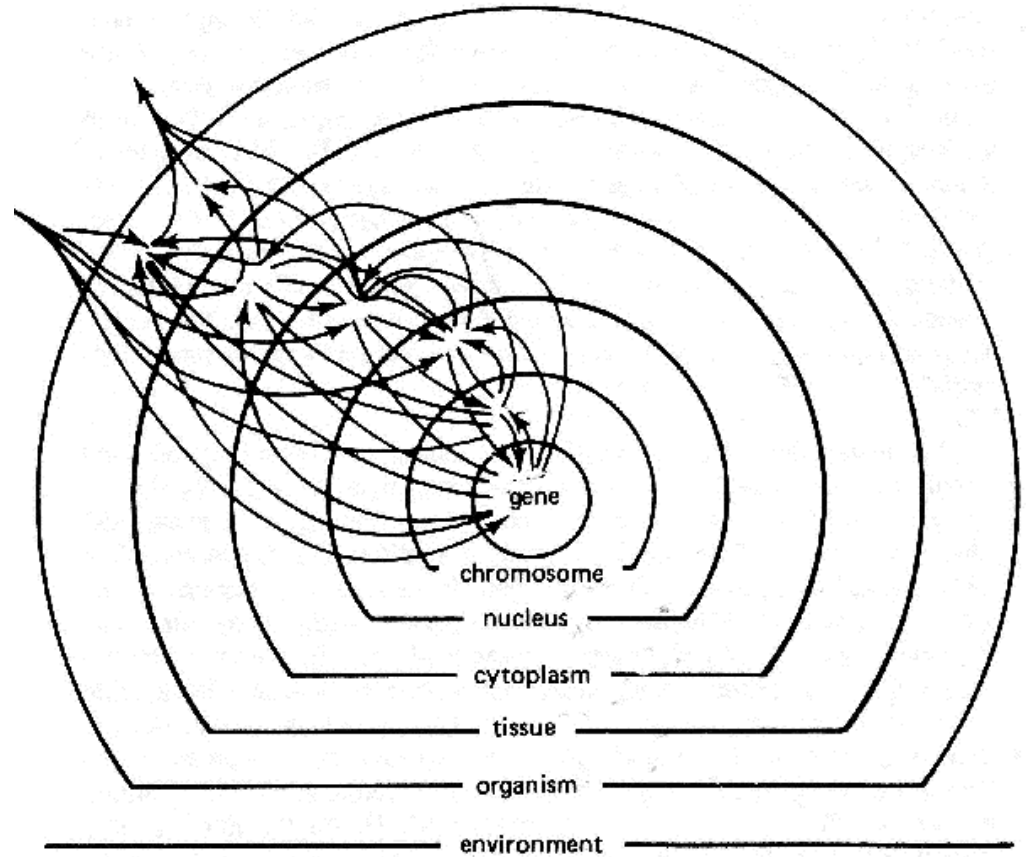
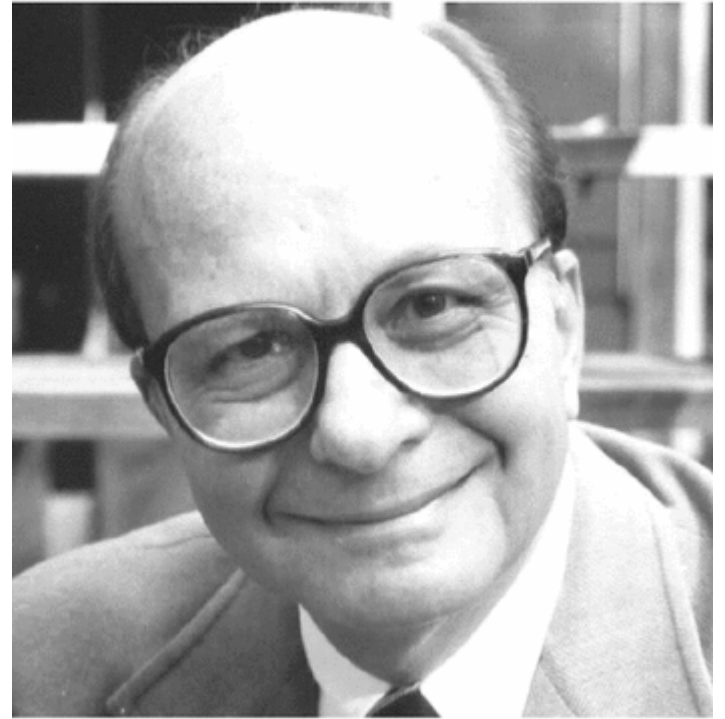


Figure 8

Mutual relationships of the hierarchically ordered subsystems of organisms.
(From Paul Weiss, *Dynamics of Development: Experiments and Inferences*, New York, 1968.)



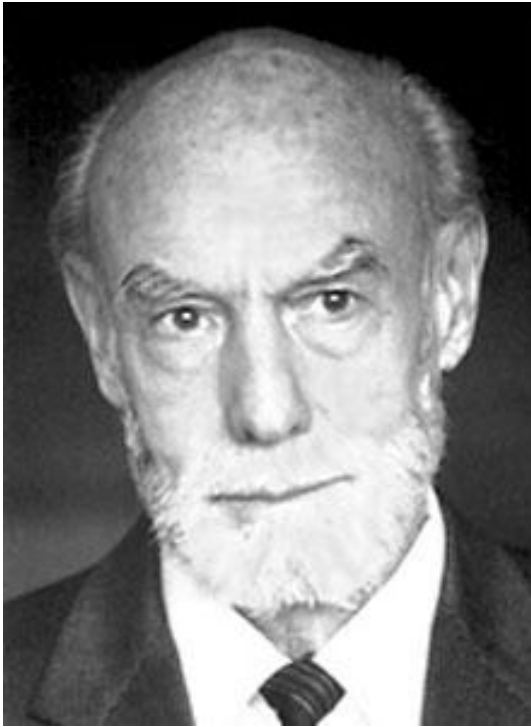
Zing-Yang Kuo (1898-1970)
Epigenesis of behaviour (1930s), anti-instinct



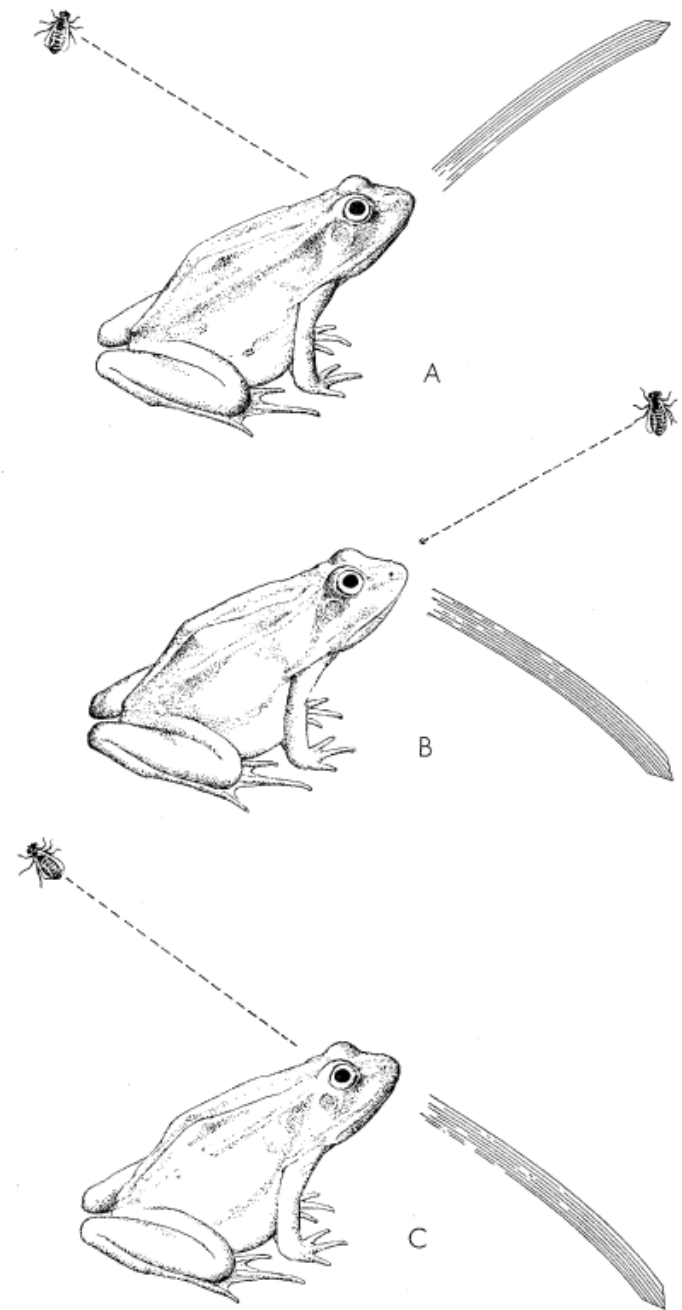
Gilbert Gottlieb (1929-2006) Probabilistic epigenesis

Reprinted from the Scientific American
Vo. 194, No. 5 May, 1956

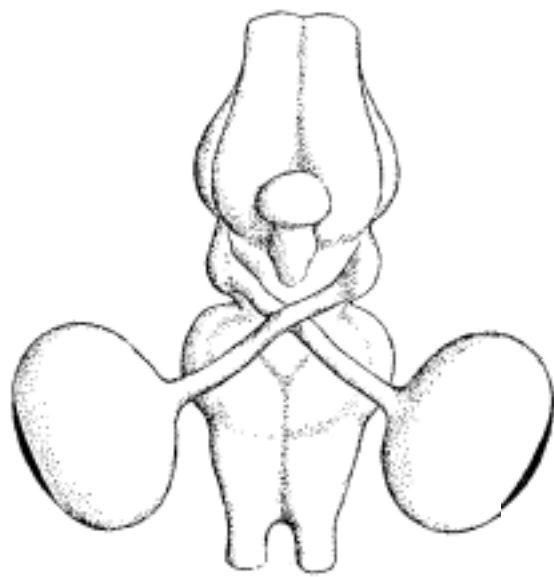
The Eye and the Brain



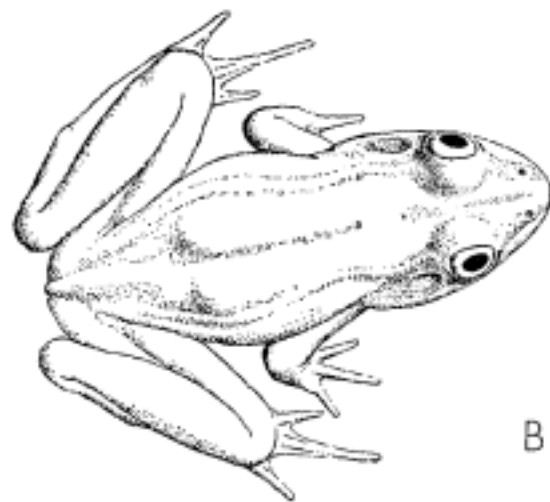
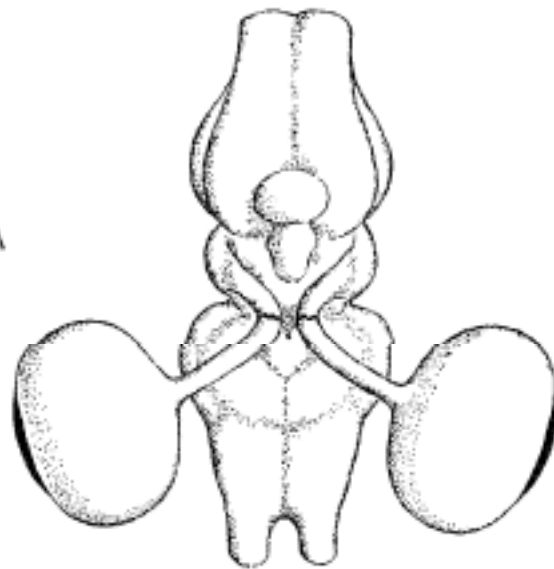
Roger Sperry (1913-1994)



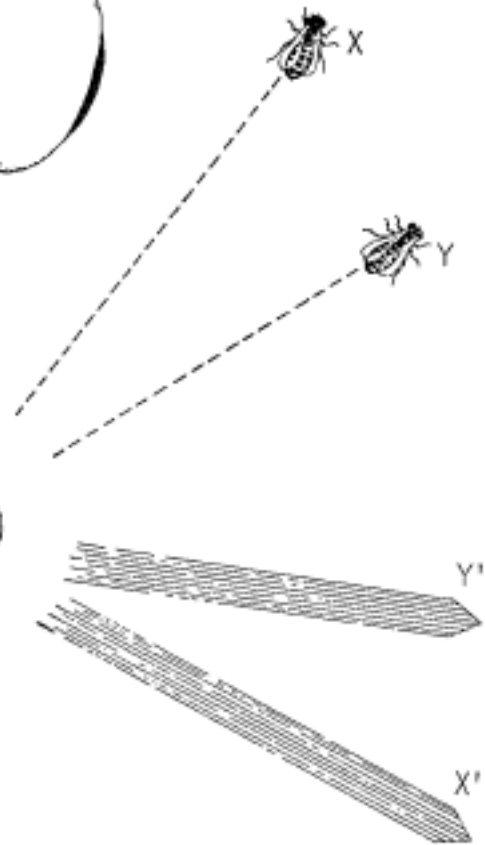
SAME OPERATIONS ON A FROG produce these effects when the animal strikes at a fly. In A the fly is above and behind a frog whose eyes have been turned by operation D on page 48; the animal strikes in the direction shown by the thick arrow. In B the eyes of the frog have been turned by operation C. In C the eyes of the frog have been turned by operation B.



A



B



Sperry 1960s. Chemoaffinity and the orderly growth of fibres

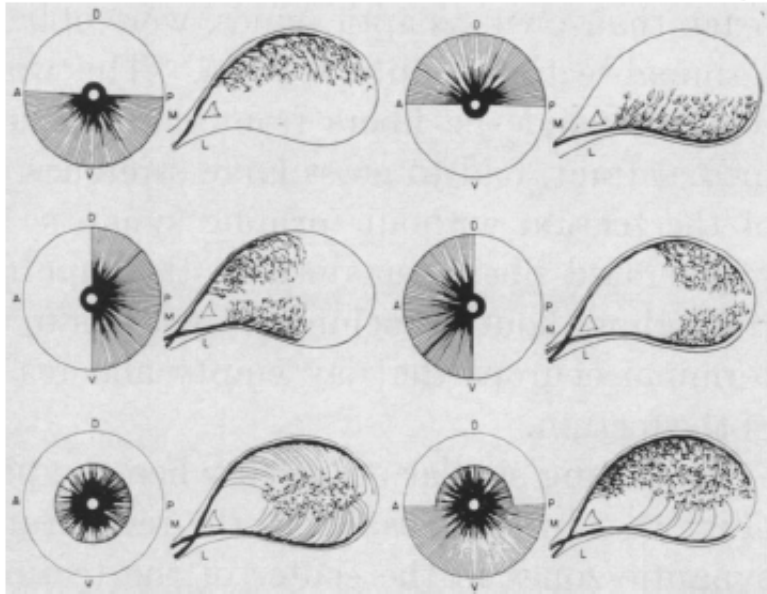


FIG. 1.—Diagrammatic reconstructions of regeneration patterns formed in optic tracts and tectum by fibers originating in different retinal halves, as indicated (after Attardi and Sperry^{4, 5}).

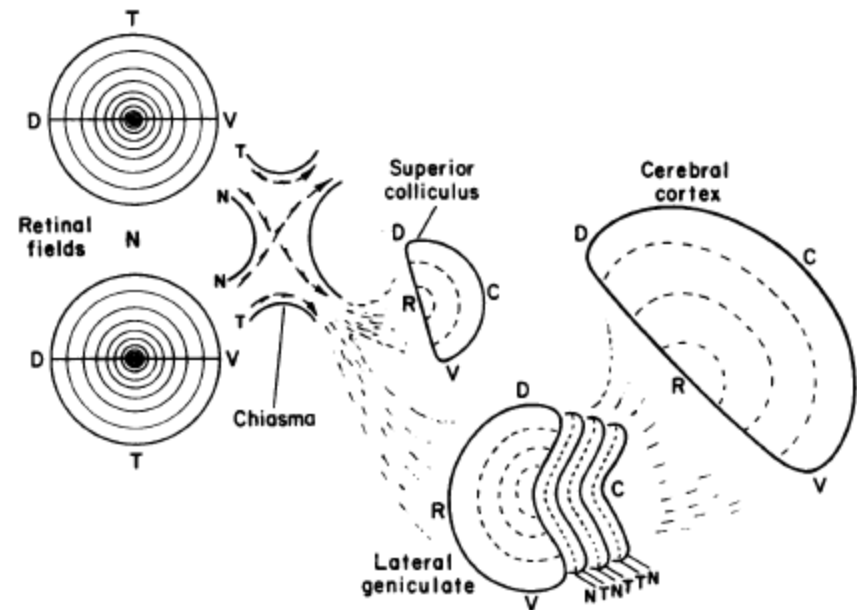
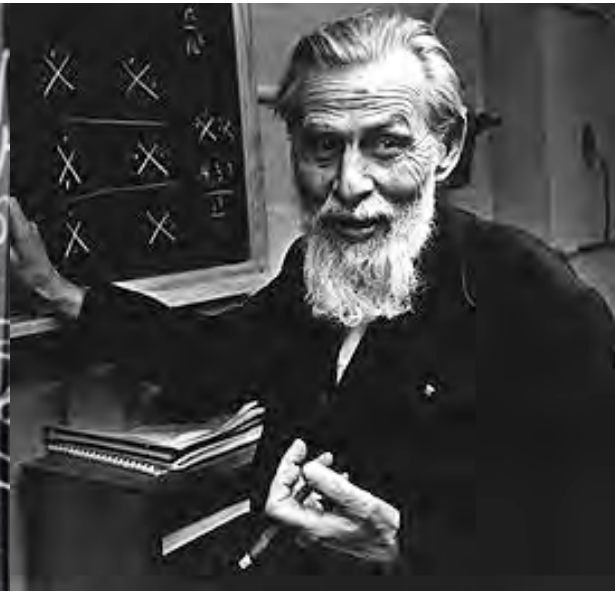
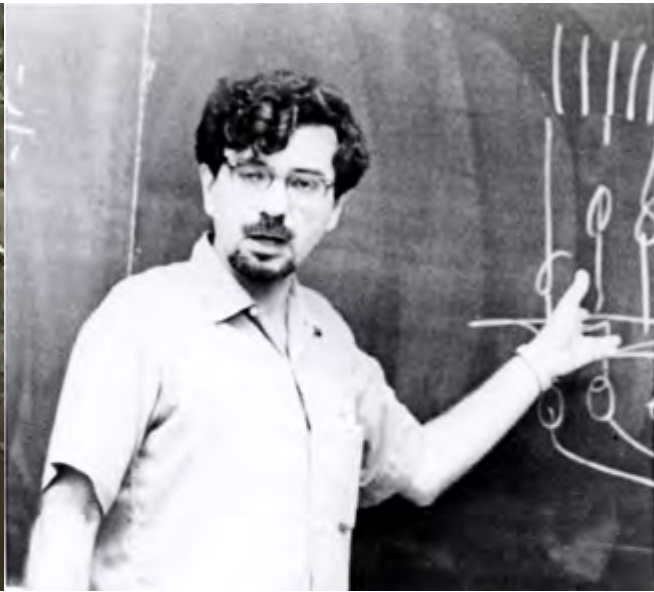
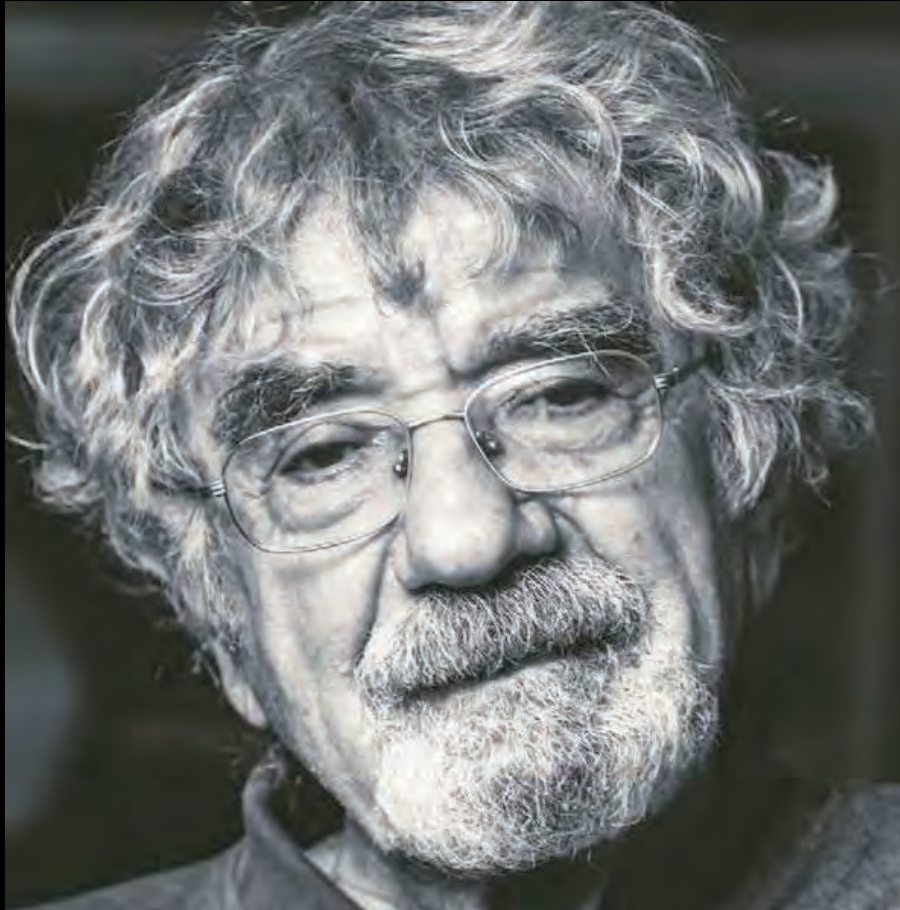


FIG. 5.—Schematic diagram indicating possible application of chemoaffinity interpretation to genesis of mammalian visual system (see text). Axial labeling of gradients for brain centers is highly tentative as the effective embryonic gradients underlying their topographic differentiation remain uncertain. D·V: dorsoventral gradient; N·T: nasotemporal; R·C: rostrocaudal.

"What the Frog's Eye Tells the Frog's Brain" Lettvin, Maturana & McCulloch 1959
(One of the most cited papers in Neuroscience)
Local processing of visual features in retinal ganglion cells



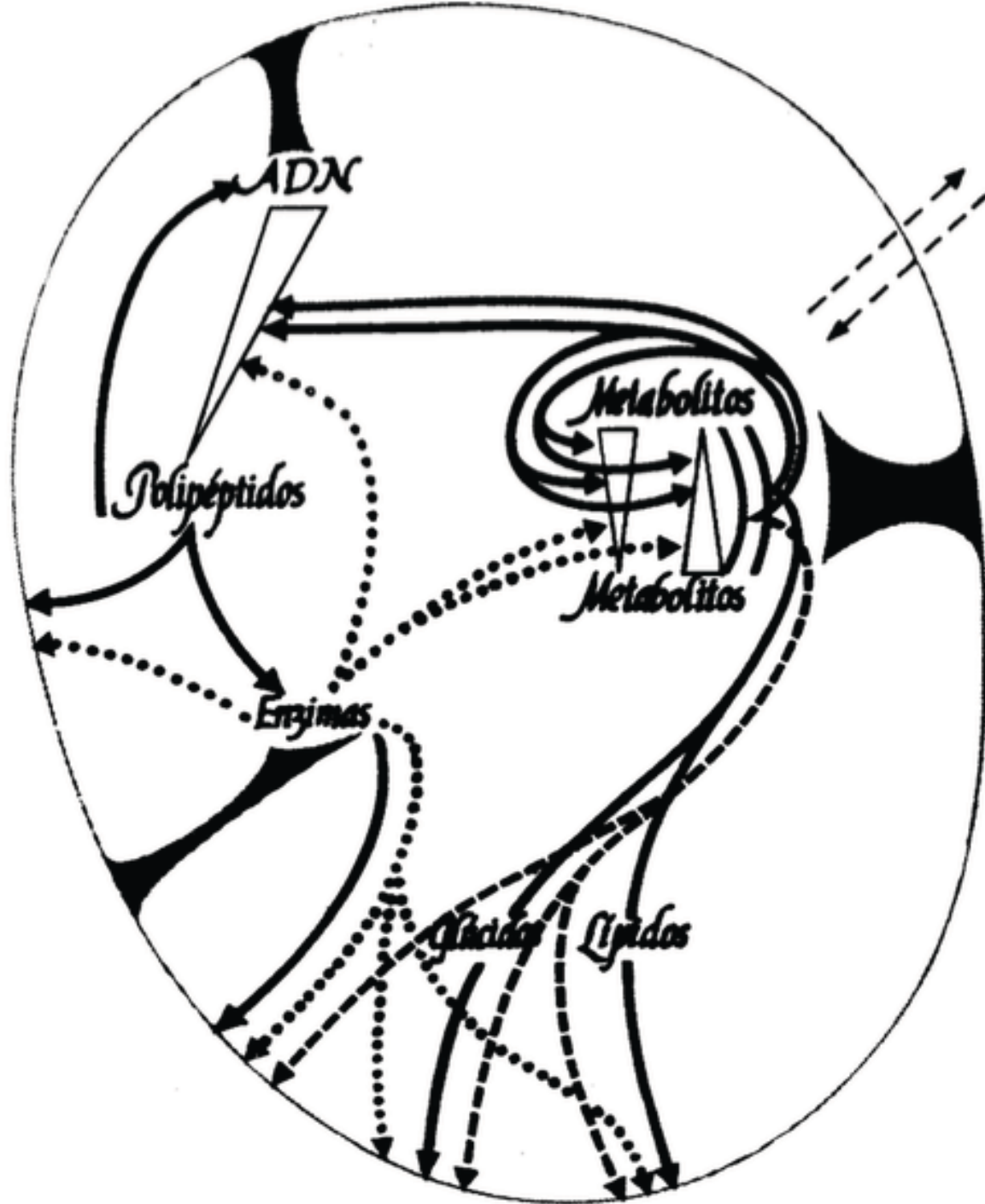
The School of Santiago



Humberto Maturana (1928 -)



Francisco Varela (1946-2001)

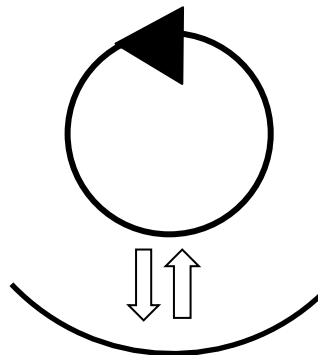


De Máquinas y Seres Vivos
(Maturana & Varela 1973)

(Autopoiesis and Cognition, Maturana & Varela 1981 –available online-)

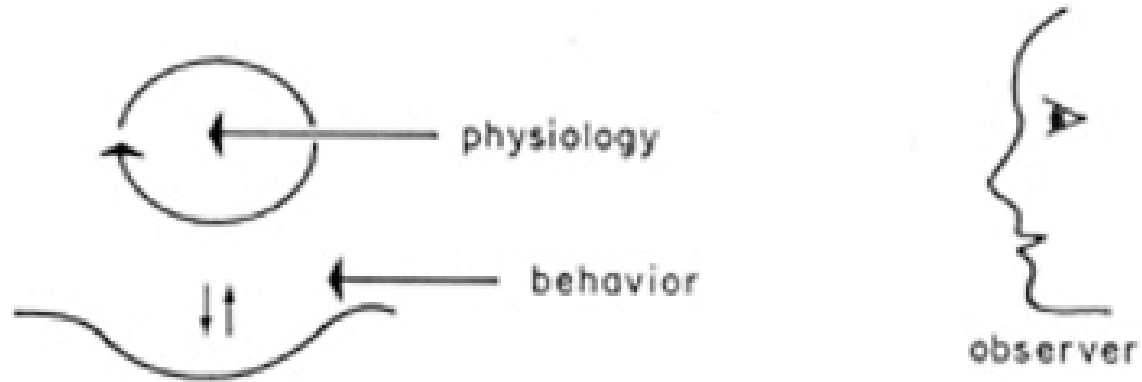
An autopoietic machine is a system organized (defined as a unity) as a network of processes of production (transformation and destruction) of components which:

- (i) through their interactions and transformations continuously regenerate and realize the network of processes (relations) that produced them; and
- (ii) constitute it (the machine) as a concrete unity in space in which they (the components) exist by specifying the topological domain of its realization as such a network.



+3000 articles per year

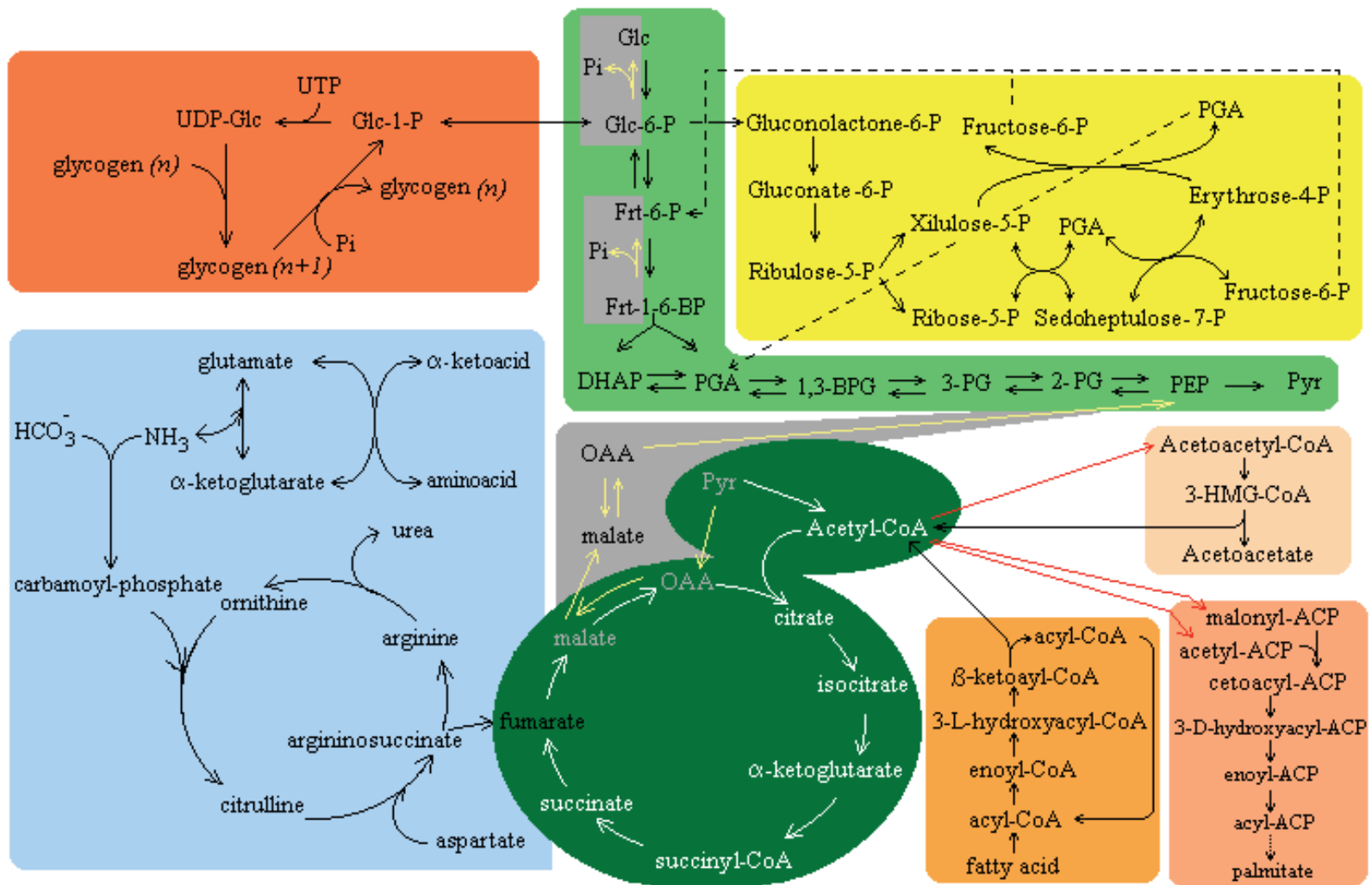
“Everything said is said by an observer”



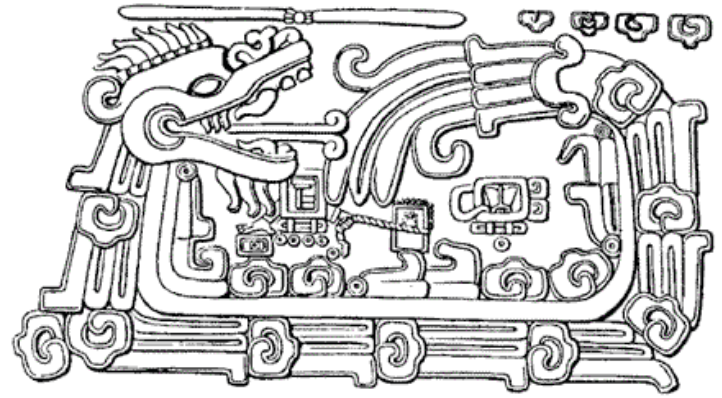
Physiology and behaviour are different domains of observation

Law of conservation of adaptation (not more or less adapted)

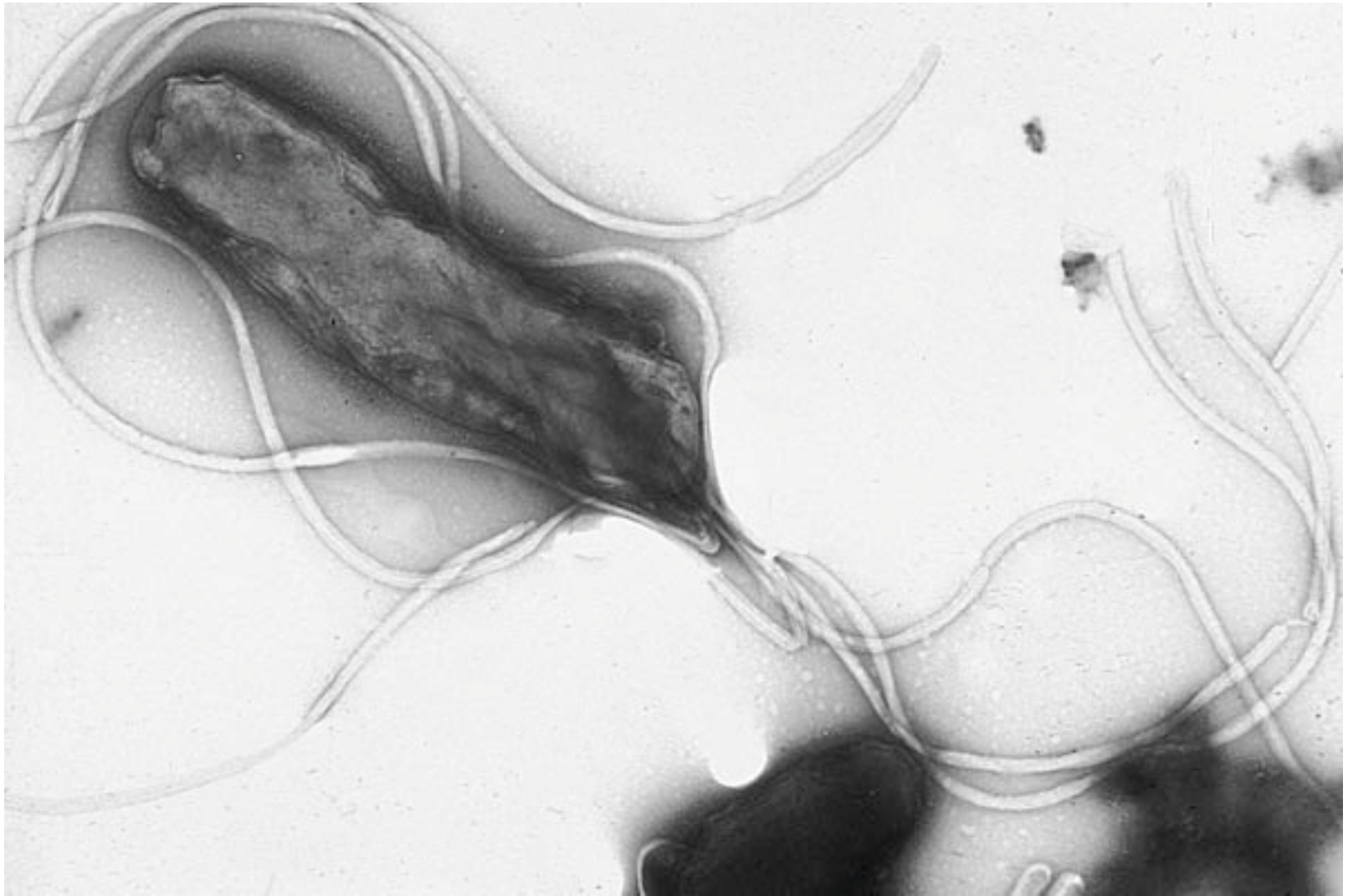




Ouroboros, and the circular nature of life



Biology of Cognition





Enaction: cognition through action

"... cognition is not the representation of a pre-given world by a pre-given mind but is rather the enactment of a world and a mind on the basis of a history of the variety of actions that a being in the world performs".

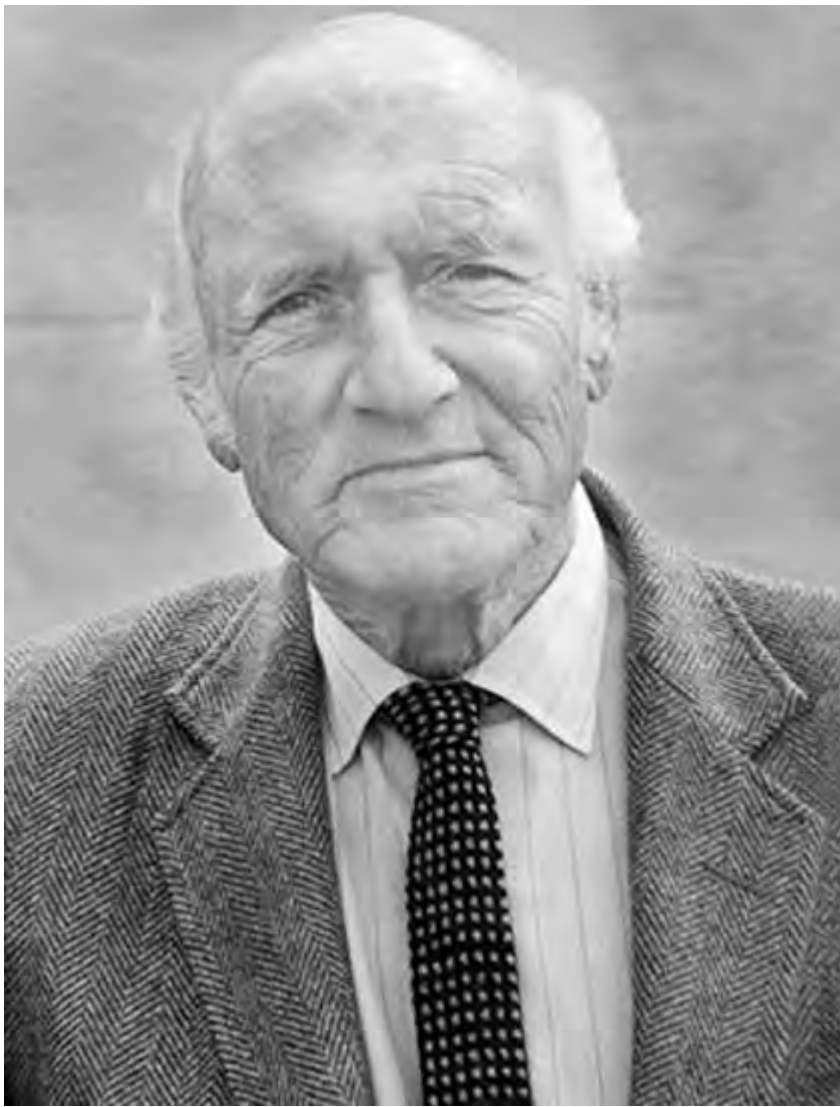
Varela et al 1991. The Embodied Mind



G. Buzsaki 2008, Rhythms of the Brain

“Representation” of external reality is therefore a continual adjustment of the brain’s self-generated patterns by outside influences, a process called “experience” by psychologists. From the above perspective, therefore, the engineering term “calibration” is synonymous with “experience.”

Paradoxically, such a view is quite recent in neuroscience research and is, of course, hard to defend if one subscribes to Aristotle’s thesis that nothing moves or changes itself. The novel idea of a “self-cause”–governed principle has emerged in several disciplines and is referred to by numerous synonyms, such as spontaneous, endogenous, autogenous, autochthonous, autopoietic, autocatakinetic, self-organized, self-generated, self-assembled, and emergent.



Ernst von Glasersfeld (1917-2010)
Radical Constructivism, Epistemology



Heinz von Foerster (1911-2002) Self-organization,
second order cybernetics

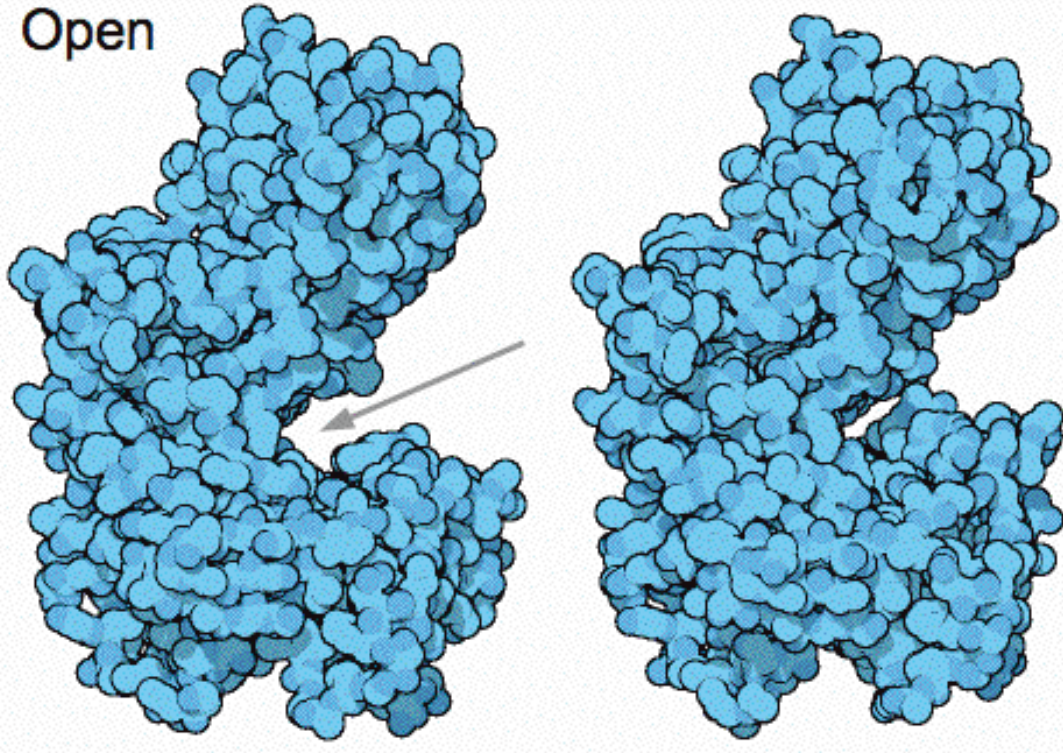
Structural determinism

- Structure-determined systems are systems such that everything that happens in them (or to them) is determined at every instant by their own structural dynamics at that instant.
- External agents may only trigger in it changes determined in its structure **without specifying them**.
- A structure-determined system, therefore, has a structure that changes following a course contingent to the course of its interactions, and whenever we live a situation that seem to violate structural determinism, we are astonished.

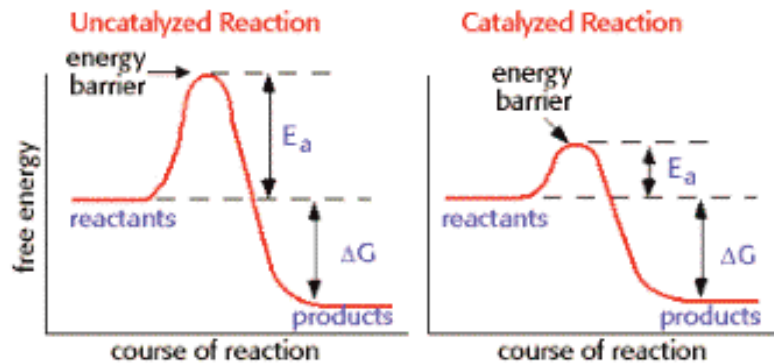
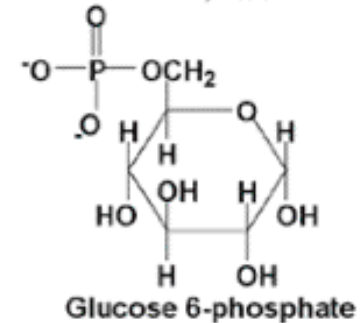
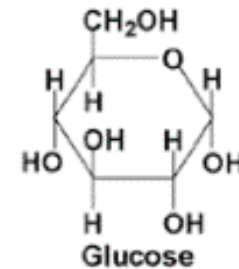
Metabolism

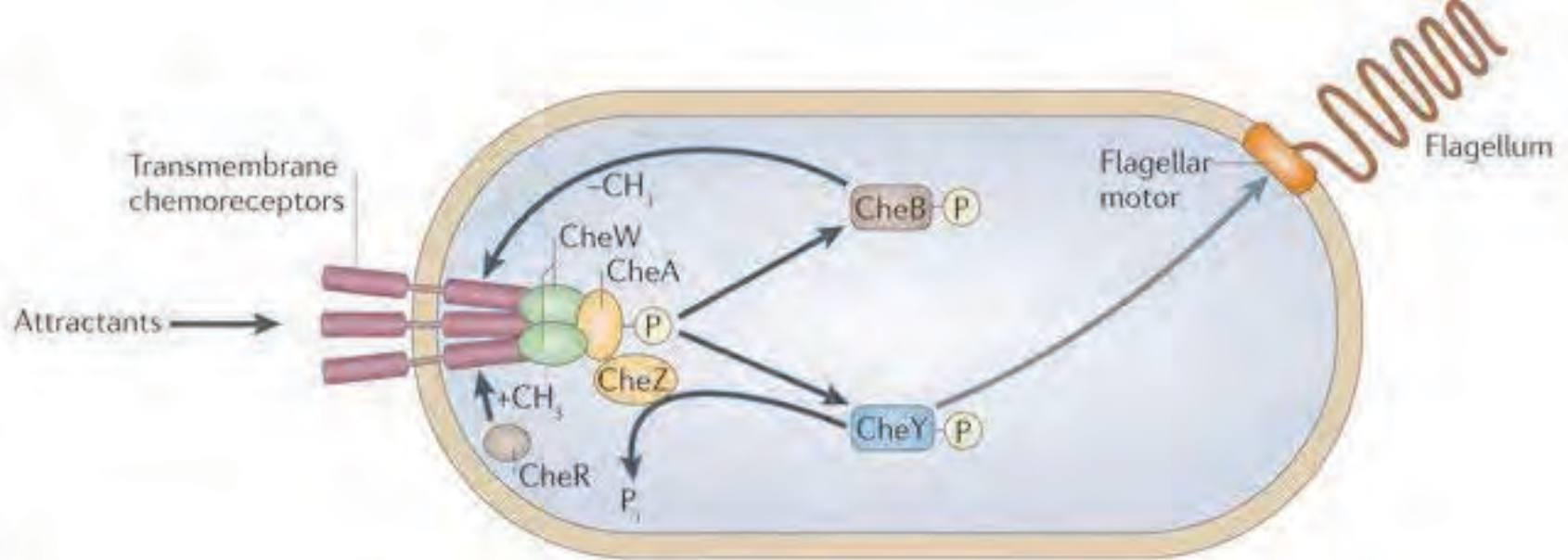
Enzymes

Open

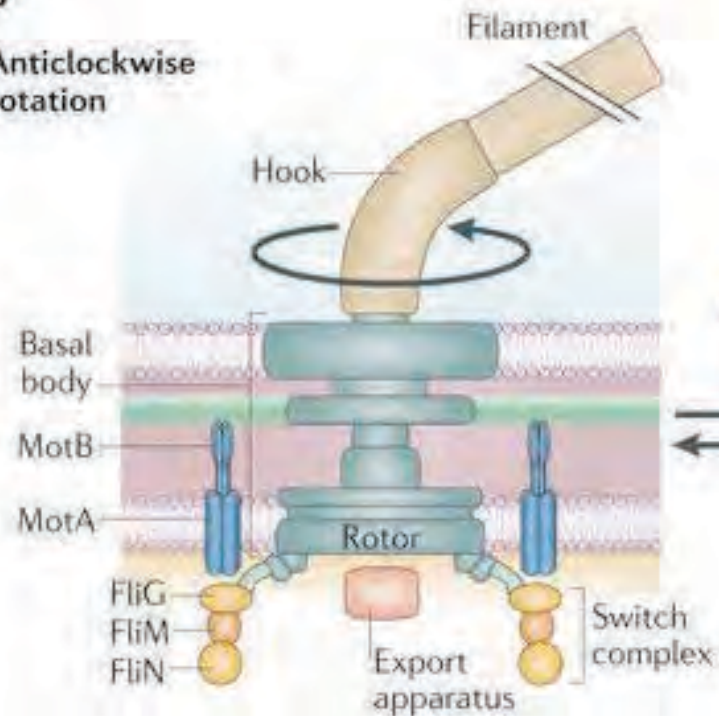


Closed

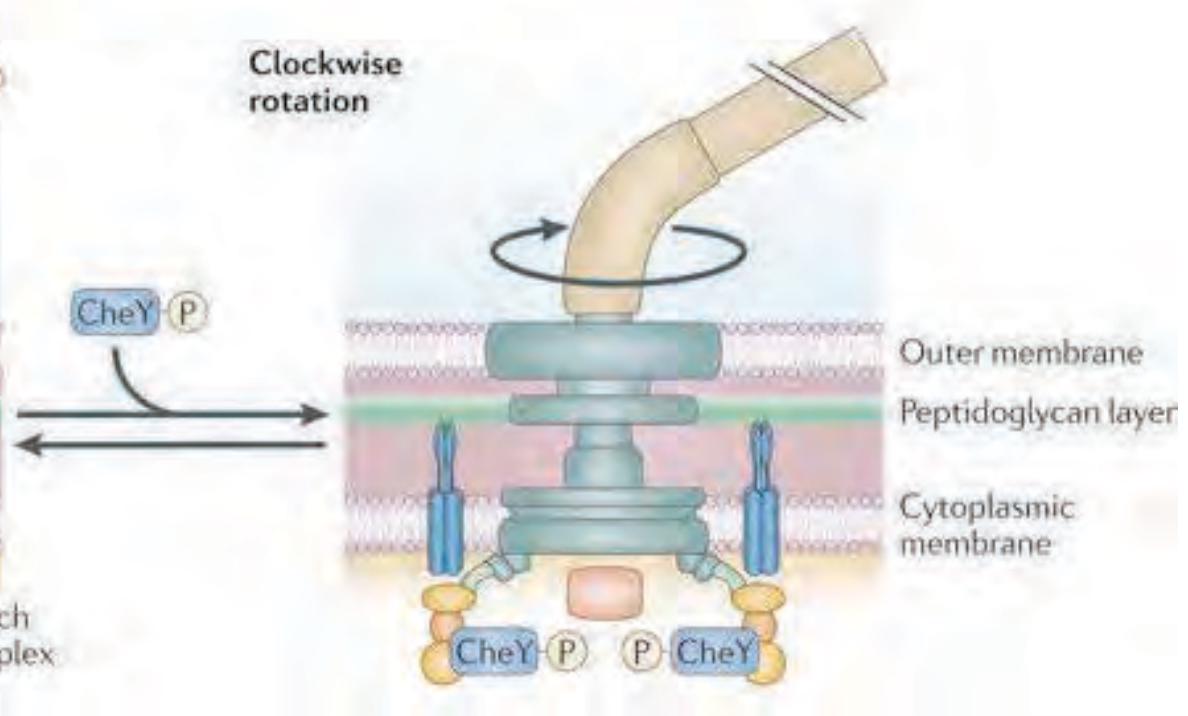


a**b**

Anticlockwise rotation

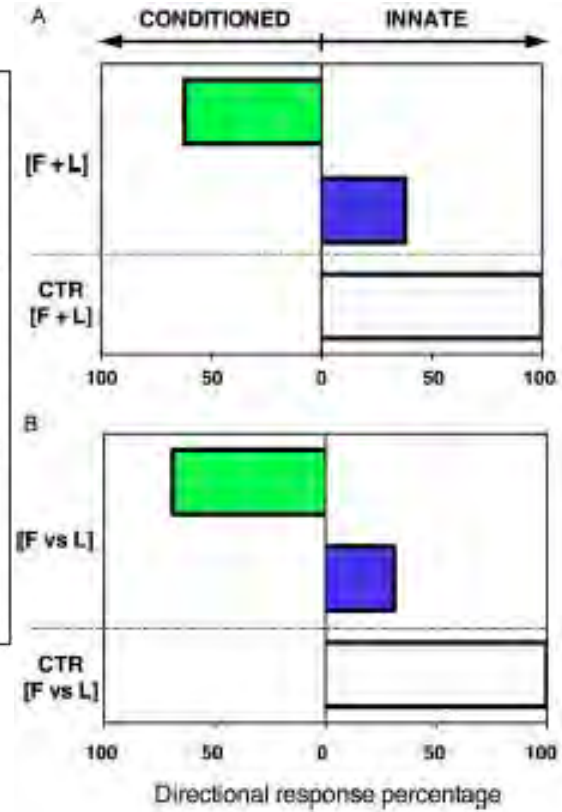
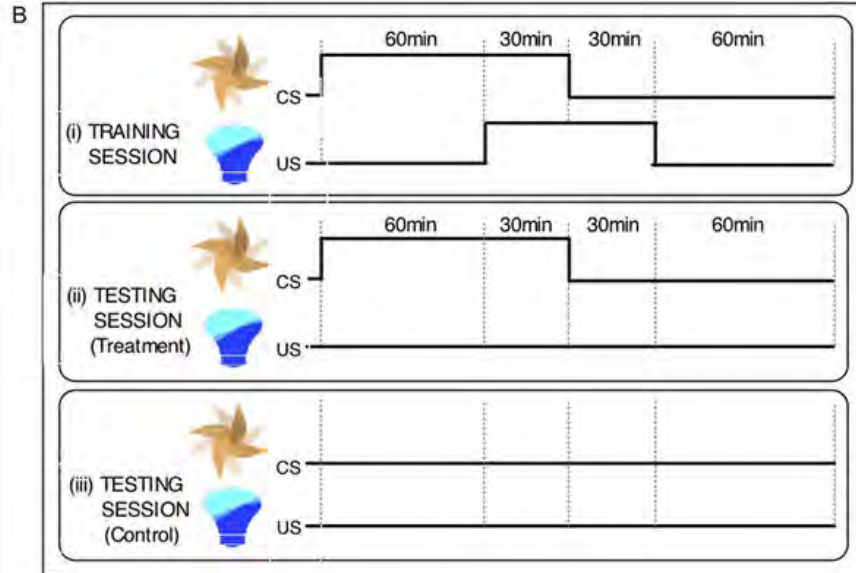
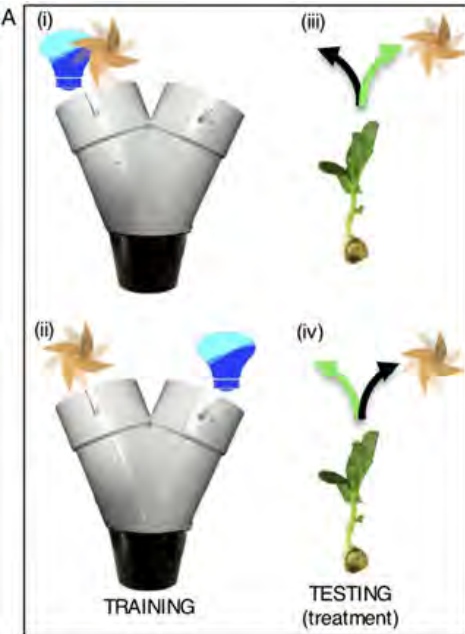


Clockwise rotation



Learning by Association in Plants

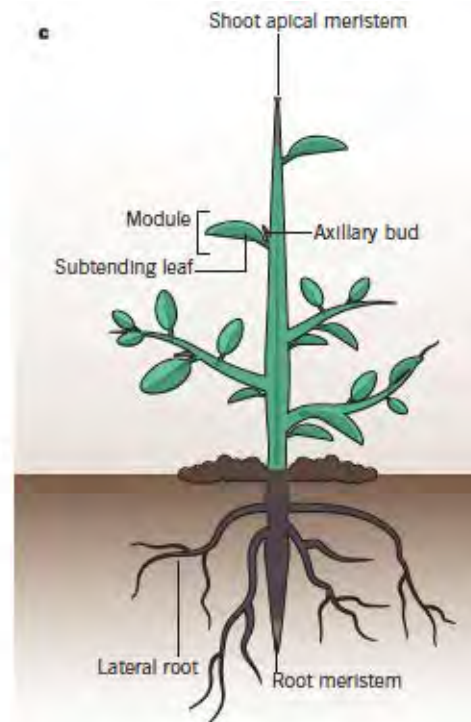
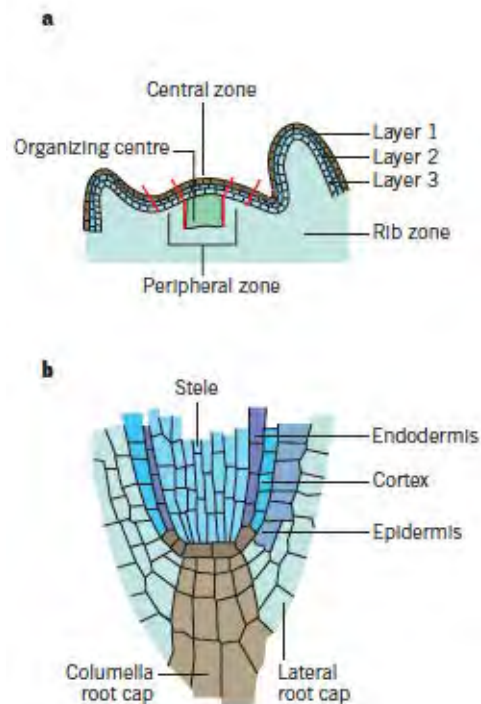
Monica Gagliano¹, Vladyslav V. Vyazovskiy², Alexander A. Borbély³, Mavra Grimonprez¹ & Martial Depczynski^{4,5}



The plant perceptron connects environment to development

Ben Scheres¹ & Wim H. van der Putten^{2,3}

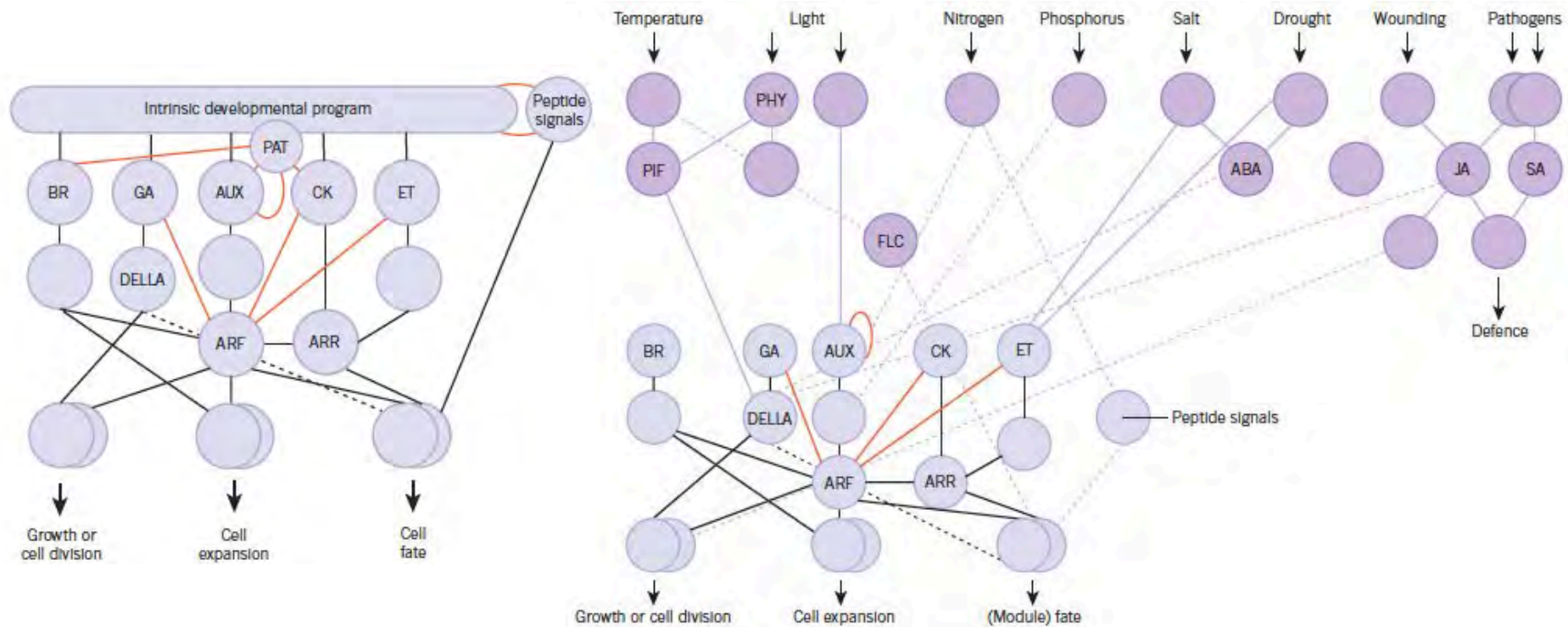
16 MARCH 2017 | VOL 543 | NATURE | 337

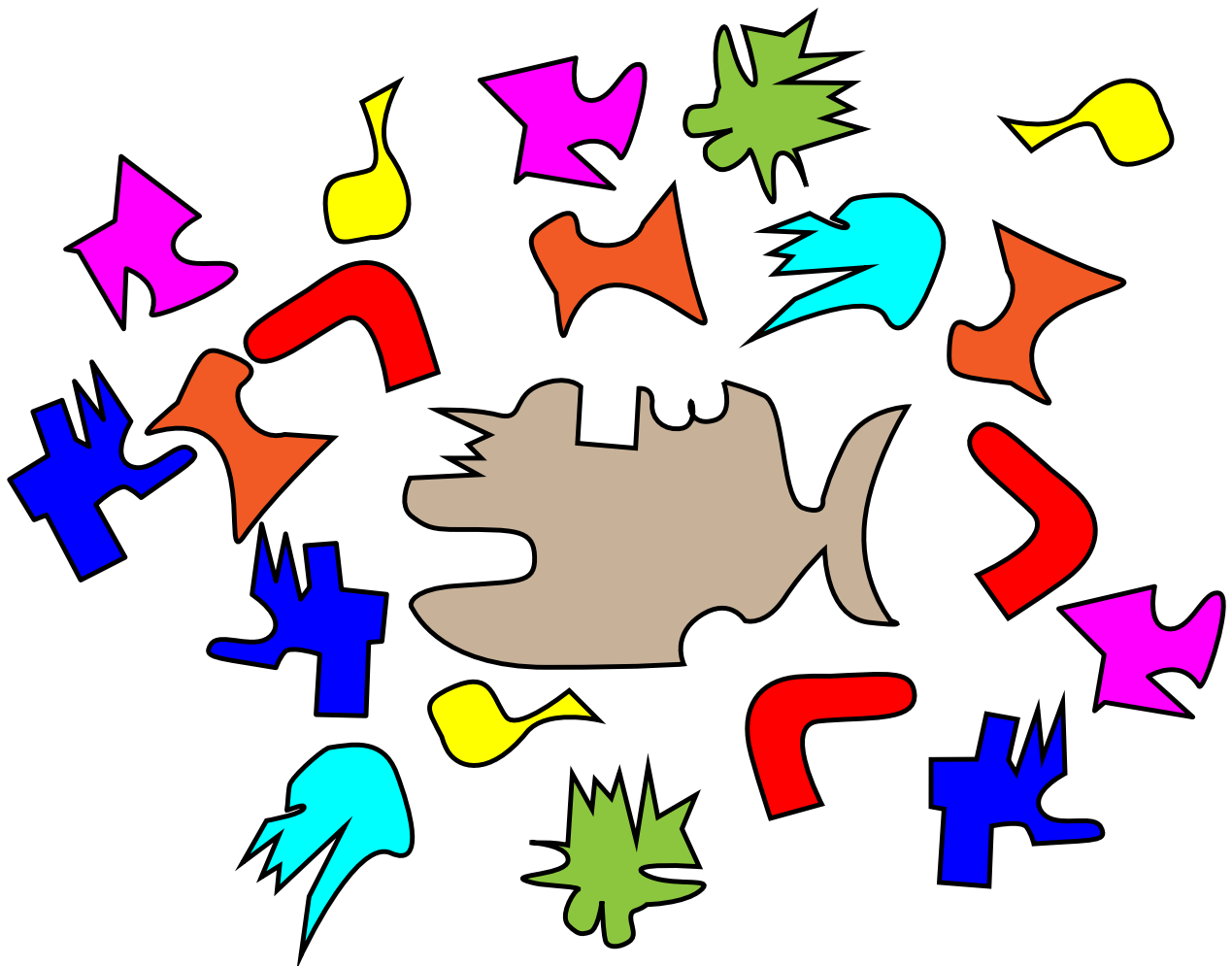


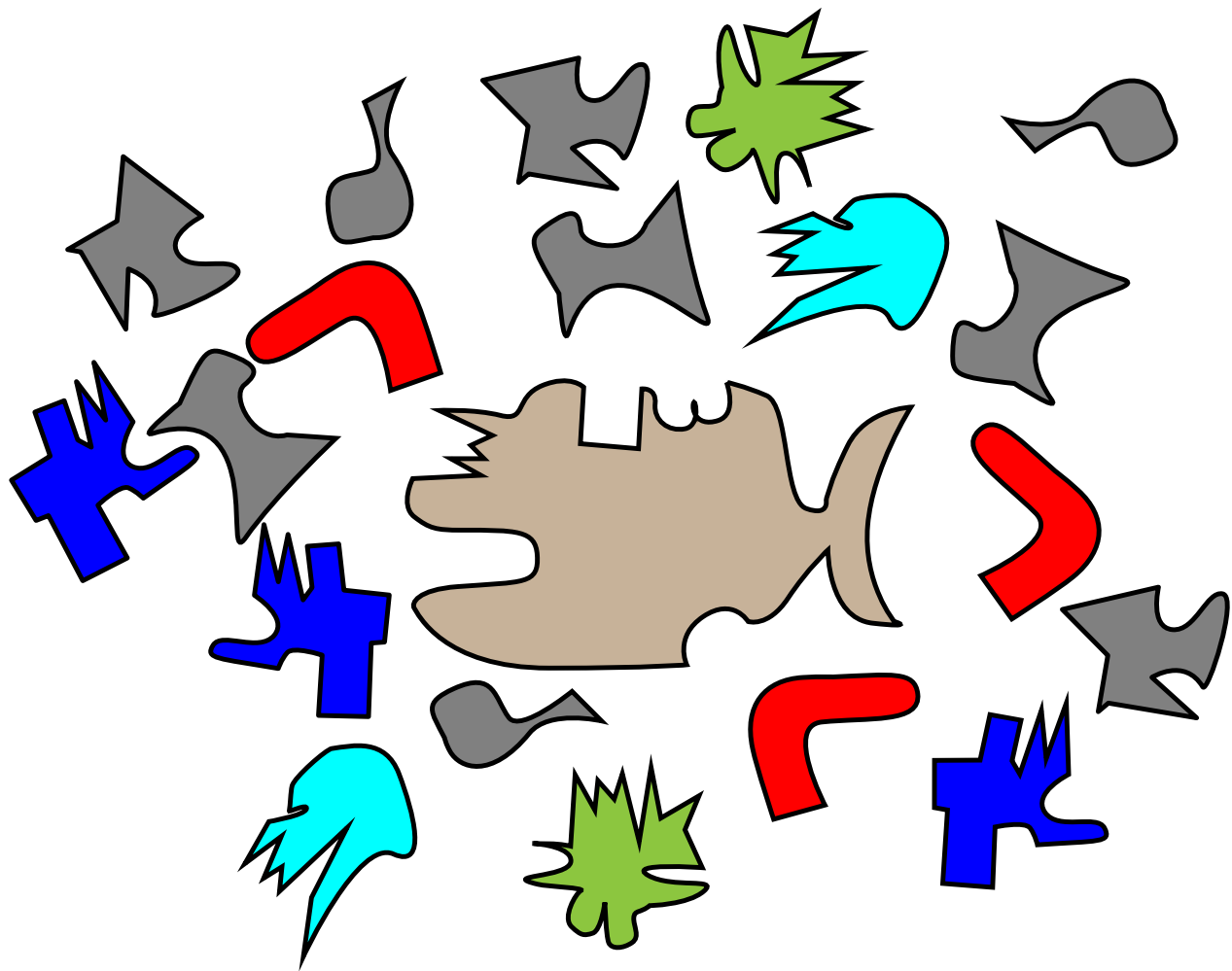
The plant perceptron connects environment to development

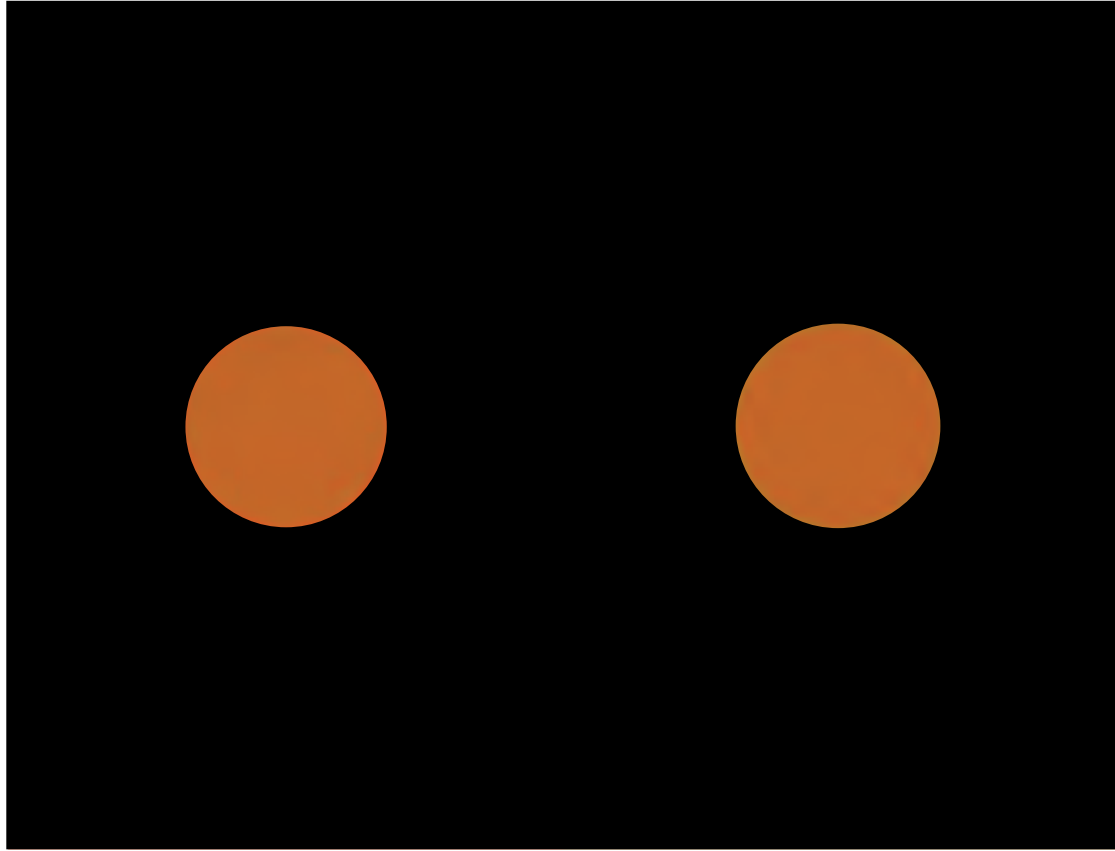
Ben Scheres¹ & Wim H. van der Putten^{2,3}

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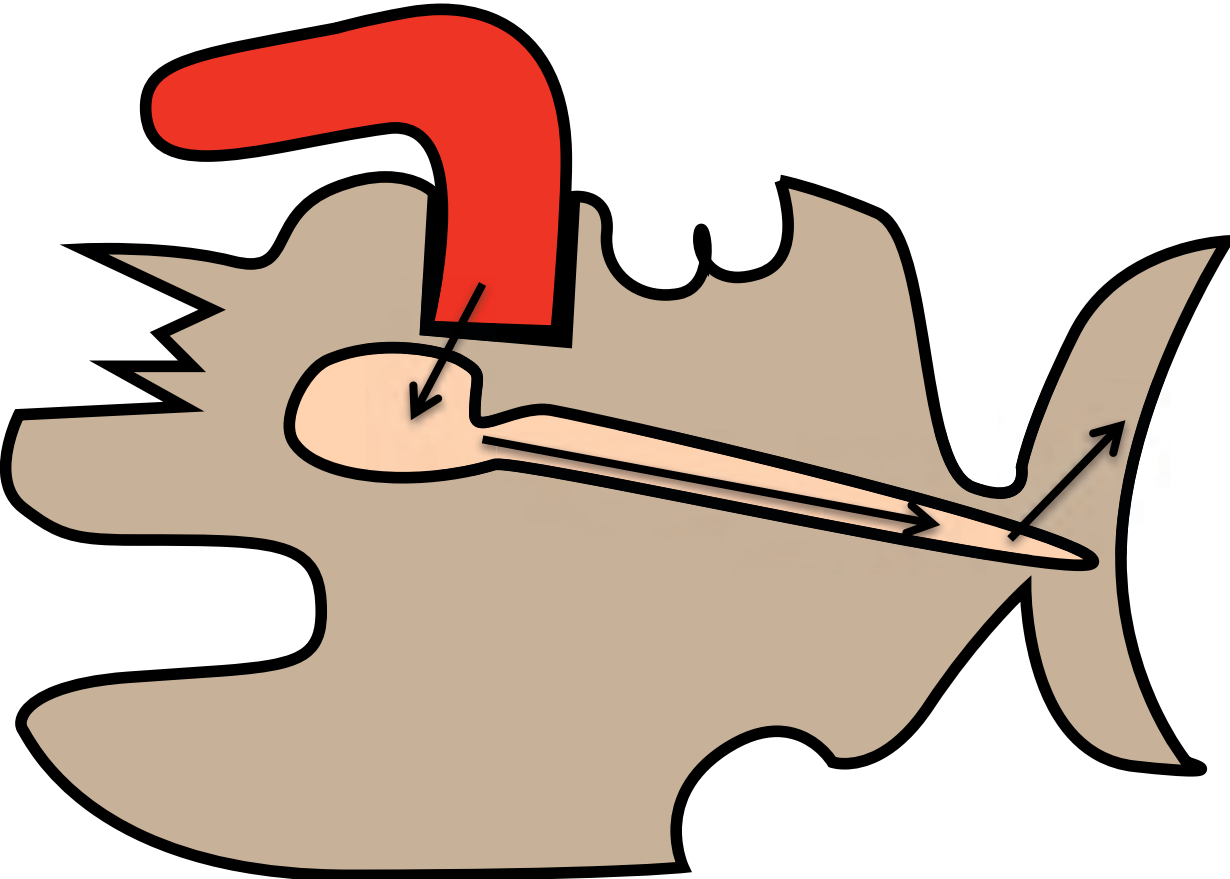




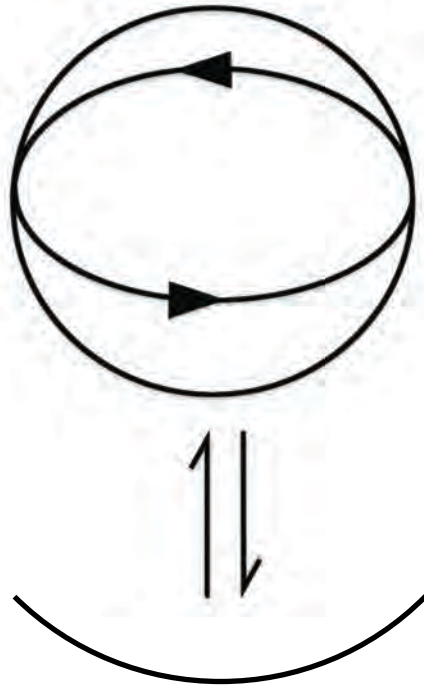




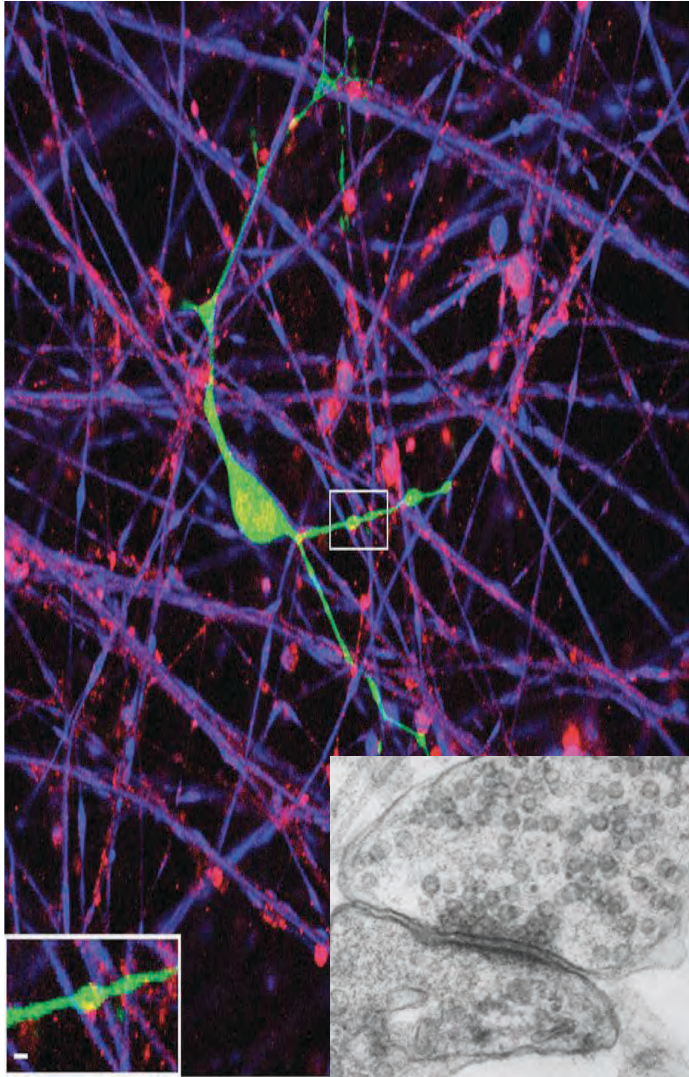
How is perception transformed into action? (and the other way around?)



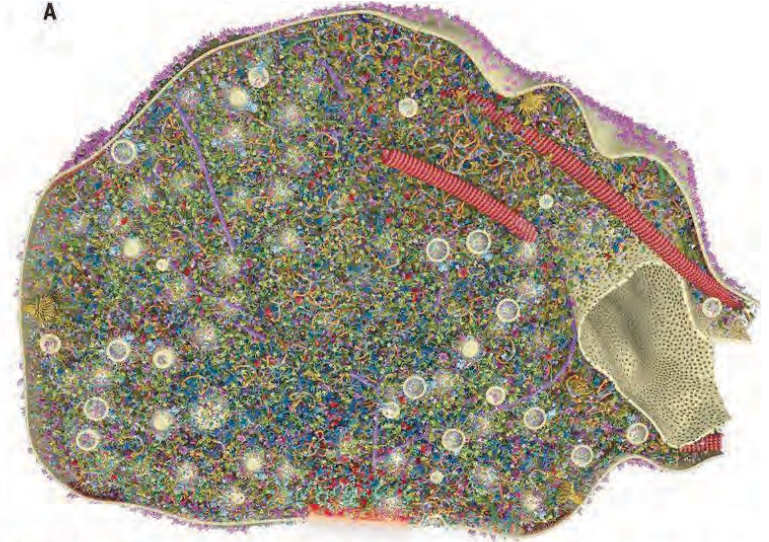
Nervous system as an operationally-closed senso-effector subsystem



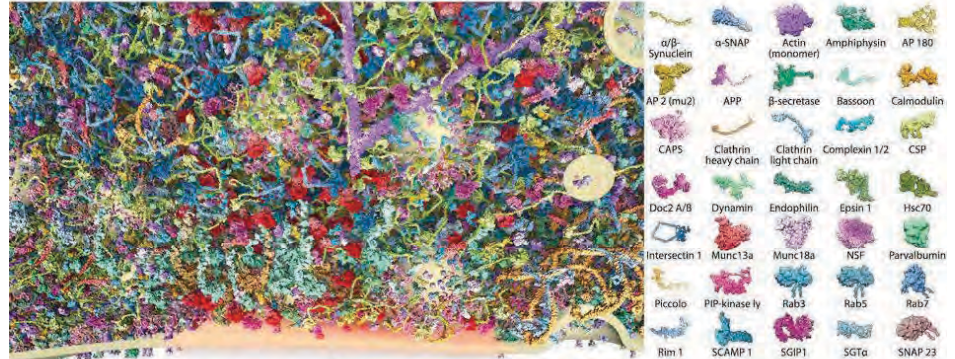
Nervous system is a structure-determined system; anything that happens to it depends on its organisation



A



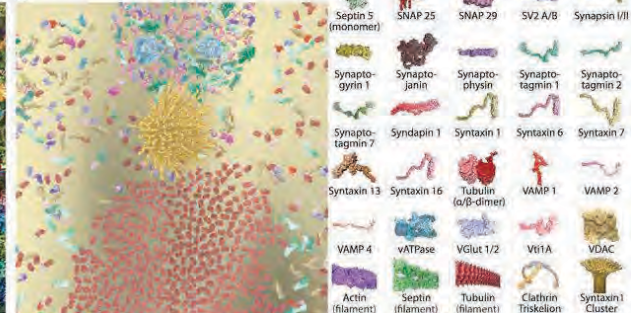
B

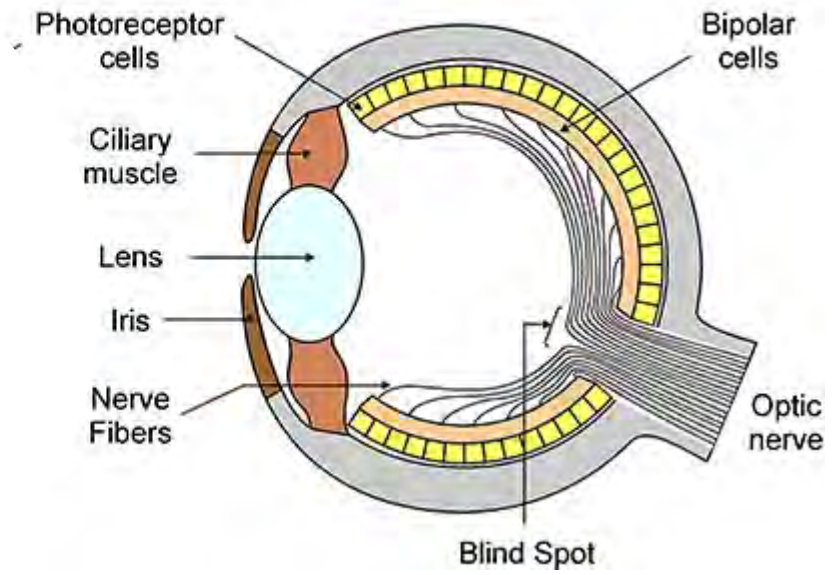


C

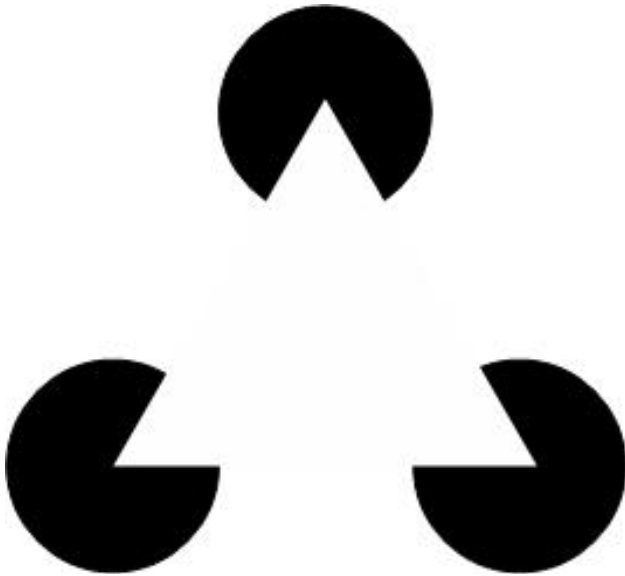


D





What do we see? How do we see it? Does it matter?



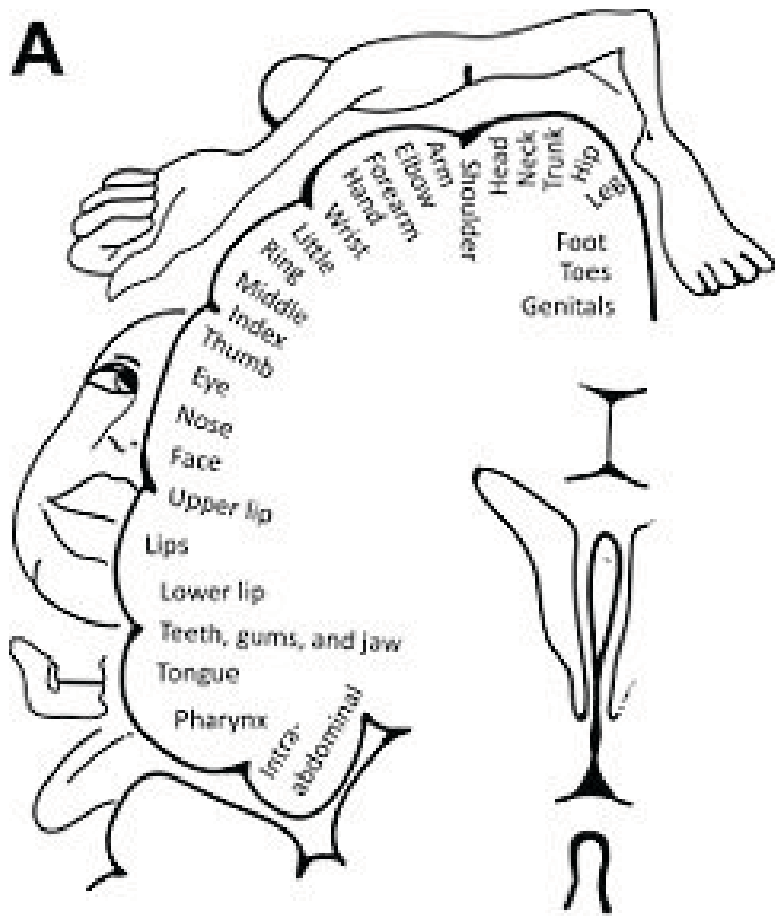
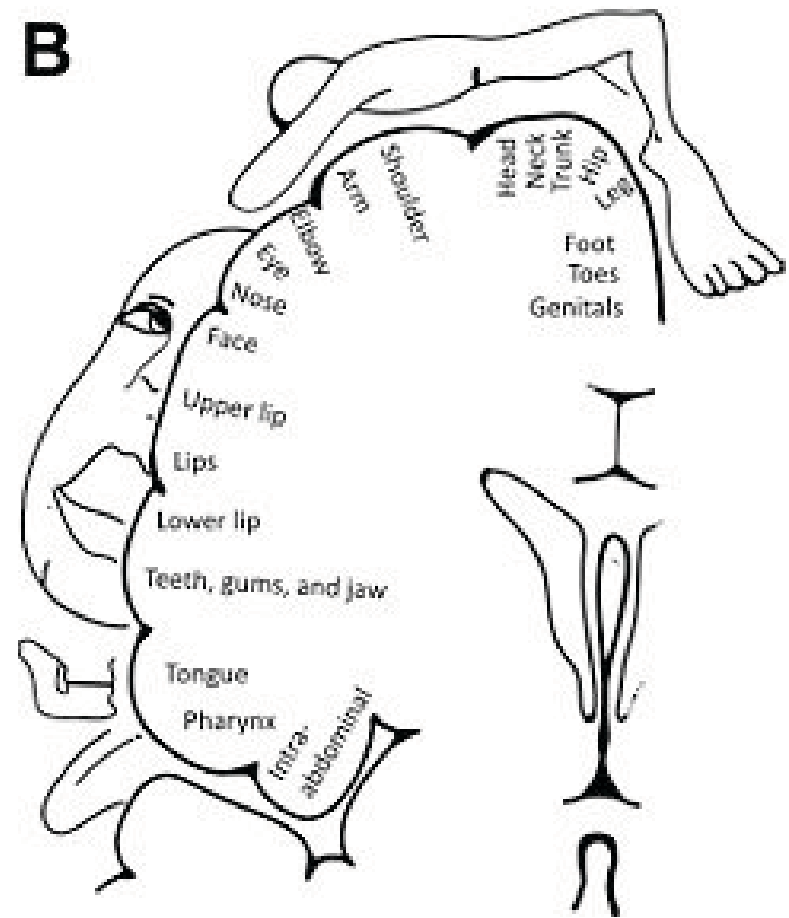
INVITED REVIEW

The perception of phantom limbs

The D. O. Hebb lecture

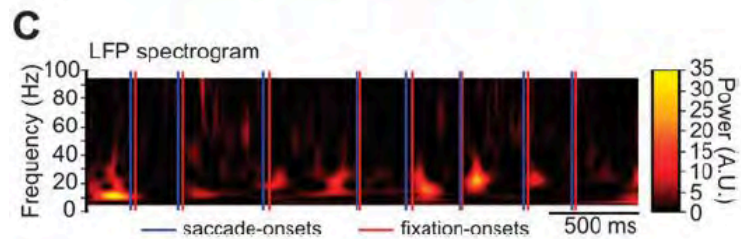
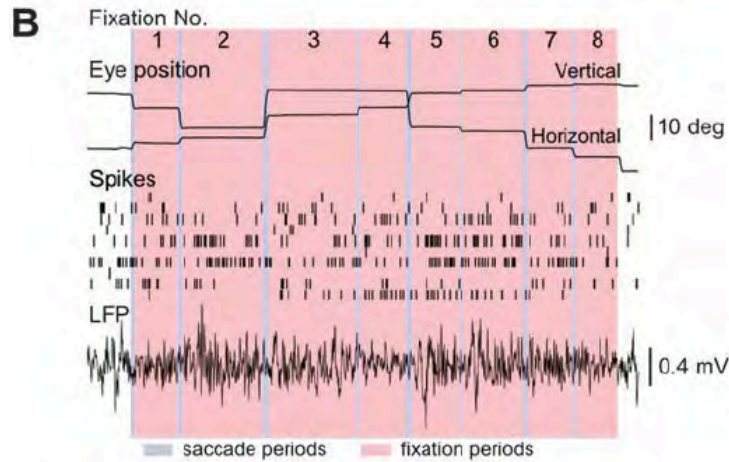
V. S. Ramachandran and William Hirstein



A**B**



A Eye-movement trace (Monkey D, session 16, trial 1)

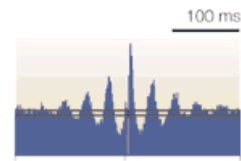
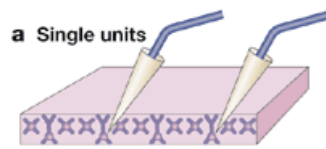


Ito et al., 2010

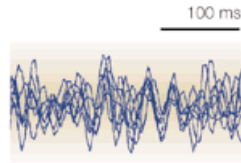
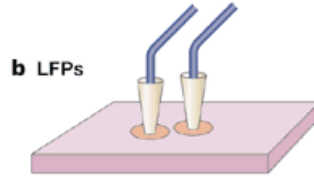
A Local scale

Spatial resolution

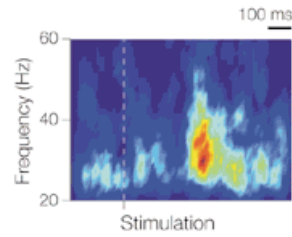
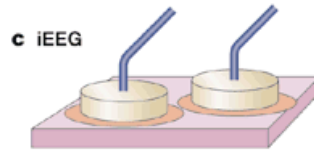
• $\sim 1 \mu\text{m}$



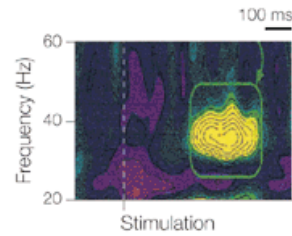
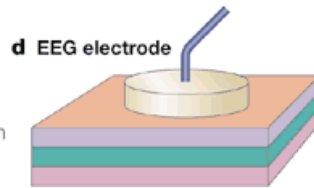
• $\sim 1 \text{ mm}$



• $\sim 1 \text{ cm}$



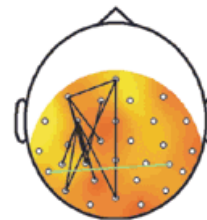
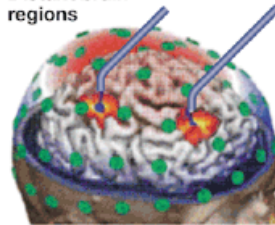
Surface diffusion



B Large scale

• $> 2 \text{ cm}$

Distant brain regions



THE BRAINWEB: PHASE SYNCHRONIZATION AND LARGE-SCALE INTEGRATION

Francisco Varela^{}, Jean-Philippe Lachaux^{*}, Eugenio Rodriguez[‡] and Jacques Martinerie^{*}*

NATURE REVIEWS | **NEUROSCIENCE** VOLUME 2 | APRIL 2001 | **229**

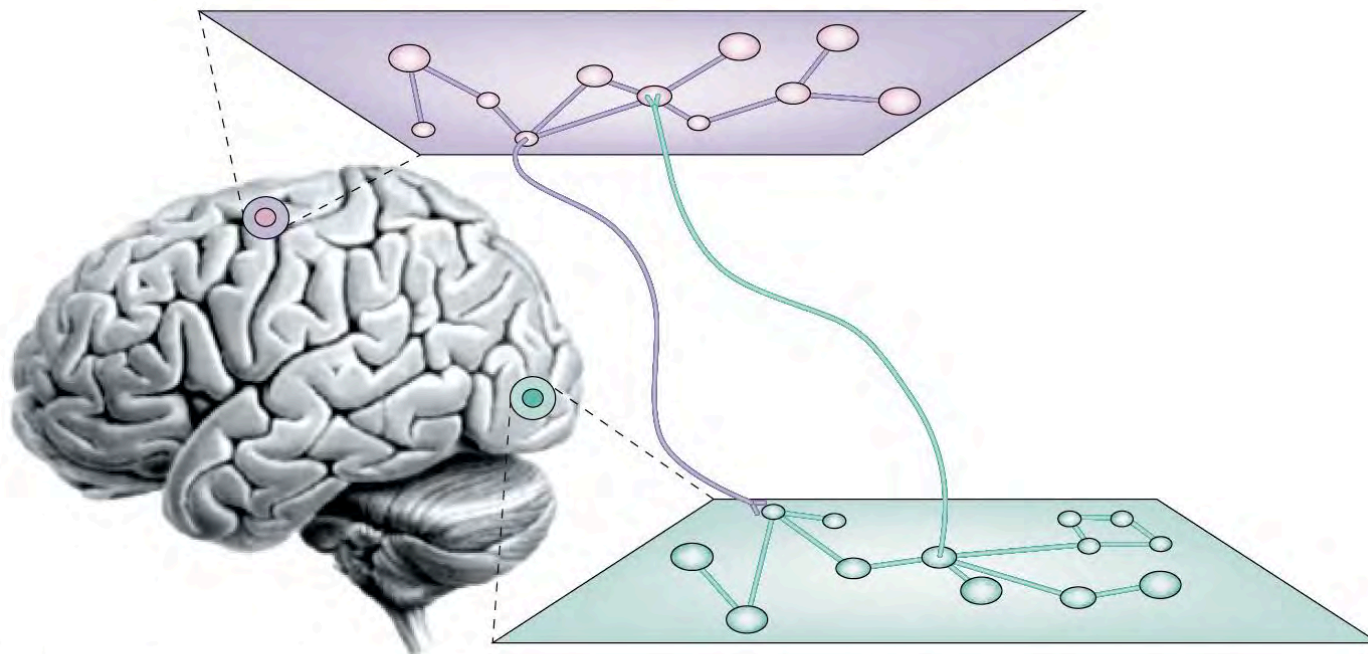


Figure 1 | **Schematic representation of transient distributed neural assemblies with dynamic long-range interactions.**





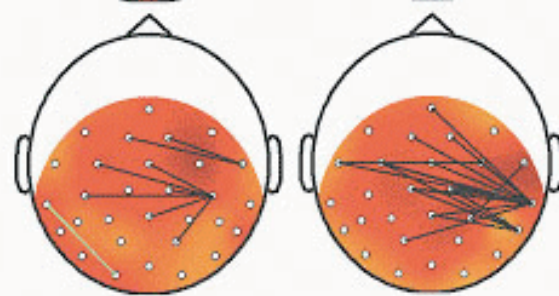
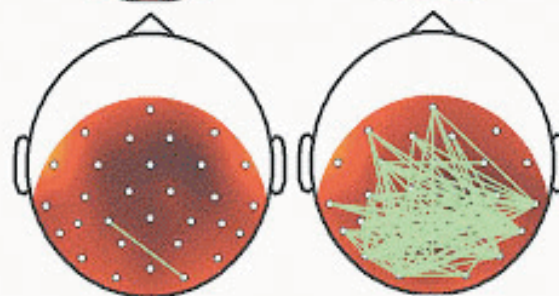
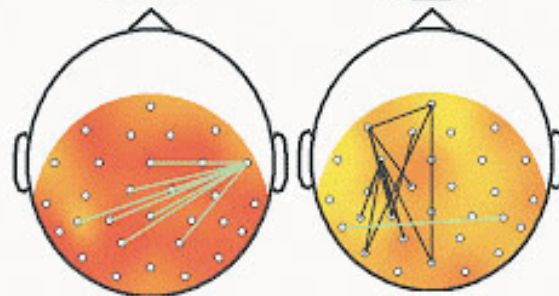
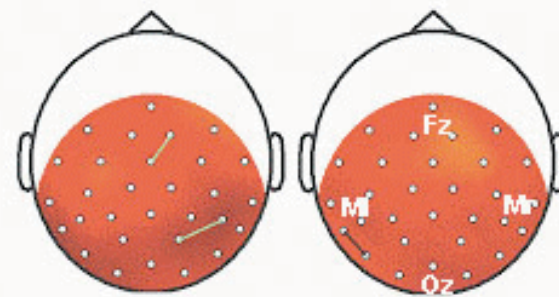
'Mooney' faces

Significant phase locking

Significant phase scattering

No Perception

Perception



0 - 180 ms

180 - 360 ms

360 - 540 ms

540 - 720 ms

Time

6

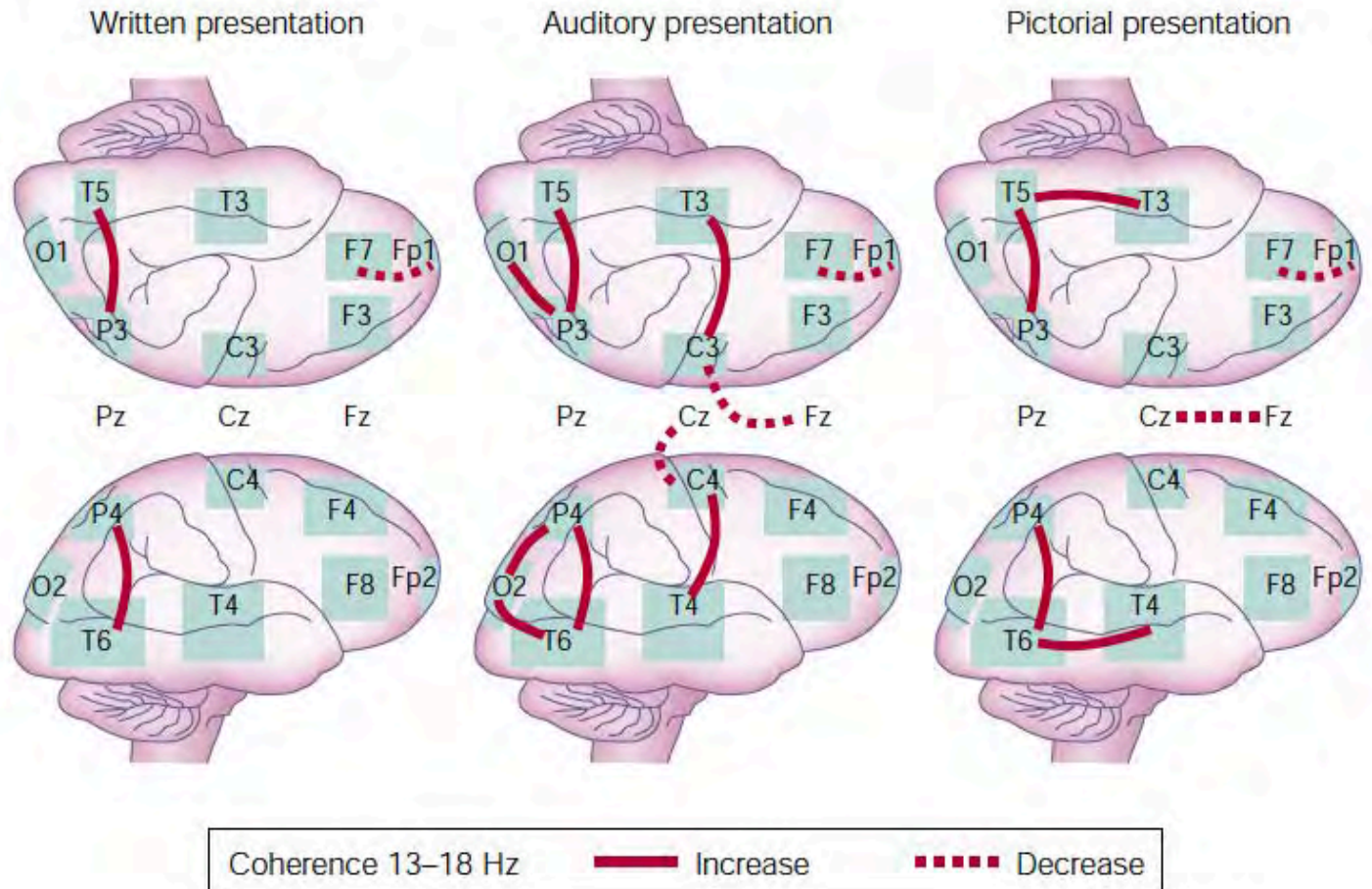
8

10

12

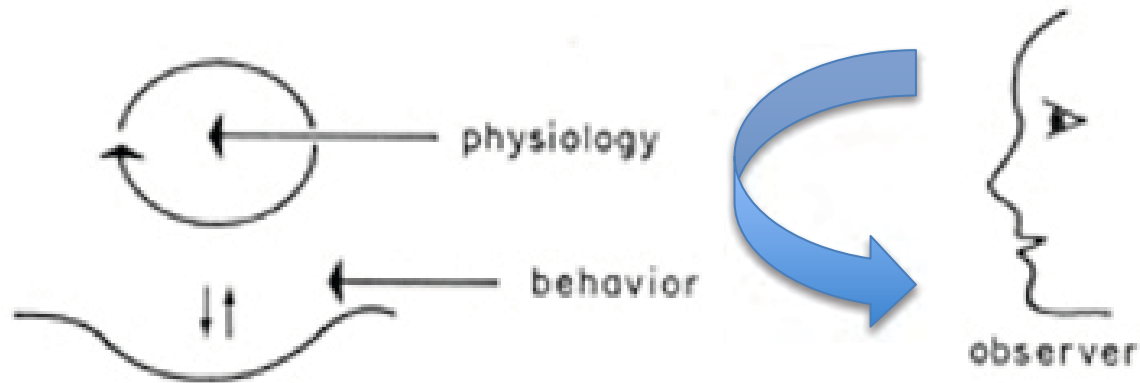
Gamma power (σ)

b Perception of objects



Neurophenomenology

Neural correlates of human experience



The focus in phenomenology is on the examination of different phenomena *as they appear to consciousness*, i.e. in a first-person perspective.