From Frog's Brains to the Language of Buildings

UCSD COGNITIVE SCIENCE STUDENT ASSOCIATION PRESENTS

THE COGNITIVE REVOLUTION 2.0

NATIONAL COGNITIVE SCIENCE CONFERENCE 2018

Saturday, April 7, 2018

Michael Arbib

Part of the Cognitive Revolution 1.0

arbib@usc.edu

Sydney University (1957-1960)

MIT (1961-1963)

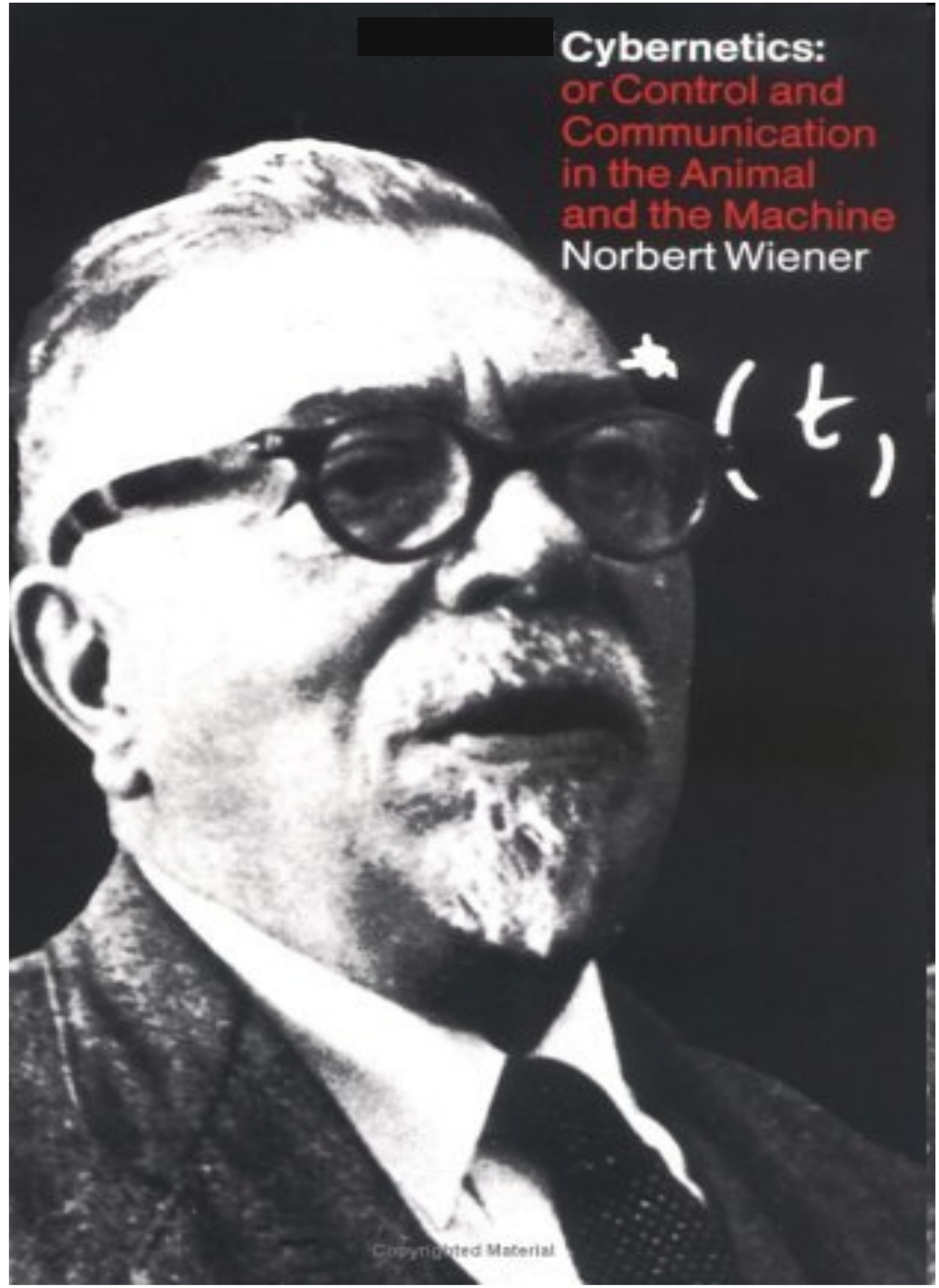
1962 – 2017 – 2072??

Part 1

The stage for Cognitive Science
was set by 1960

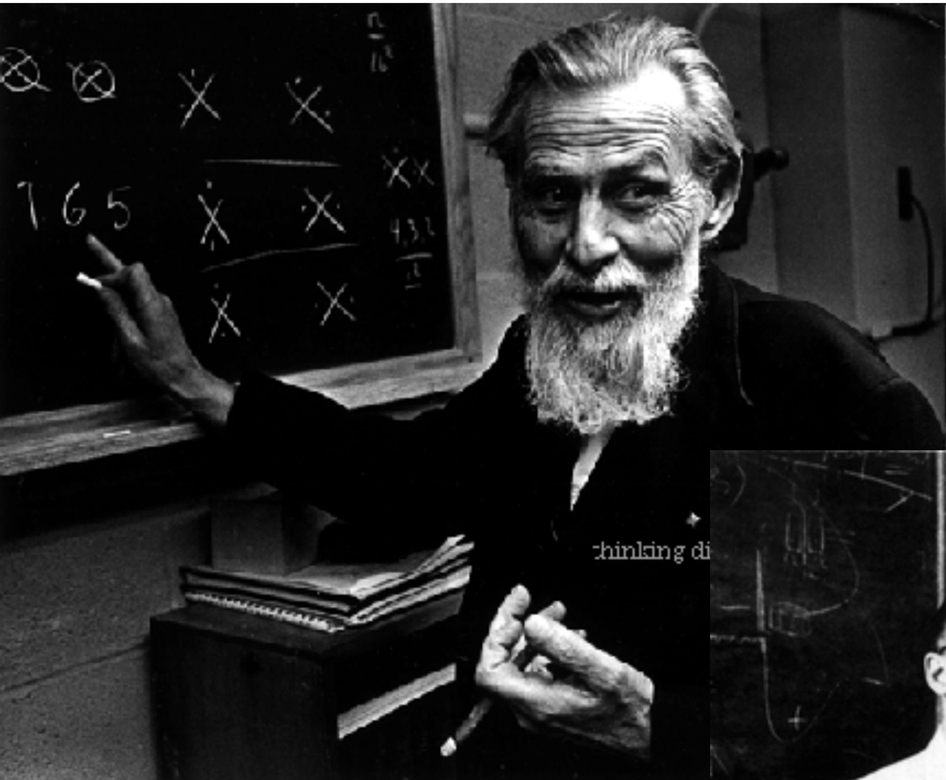
Cybernetics 1.0
or
Cognitive Science (minus 1.0)

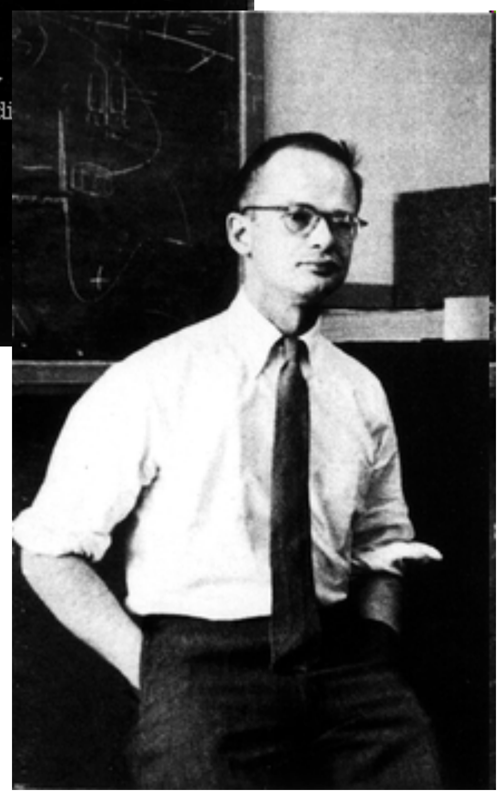
Cybernetics



1948/1961

Neural Nets, Finite Automata, and Turing Machines

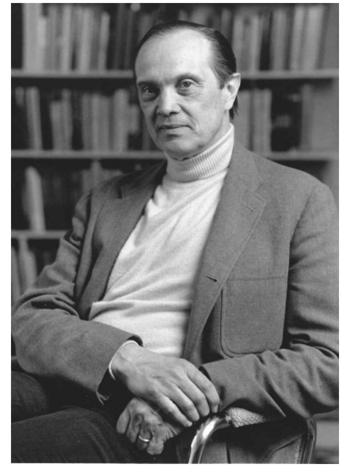


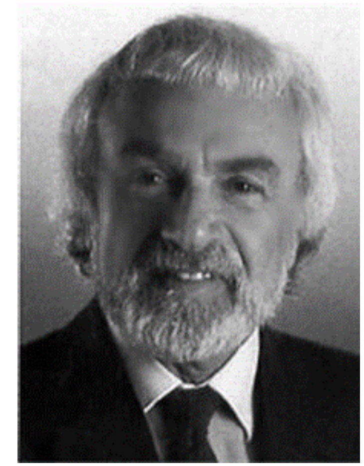


1943
1947

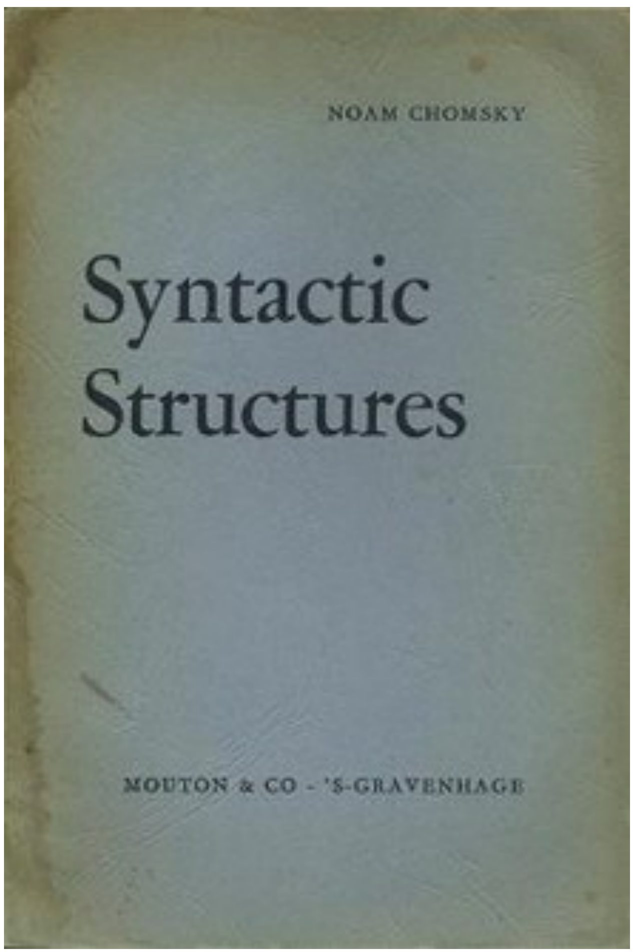
1936

Linguistics and Psychology

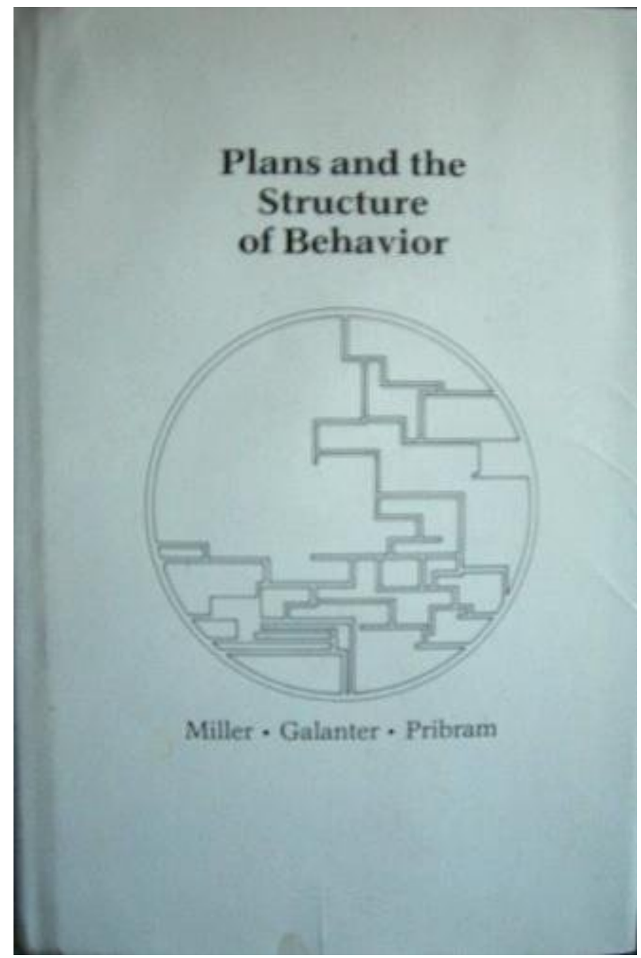




1957

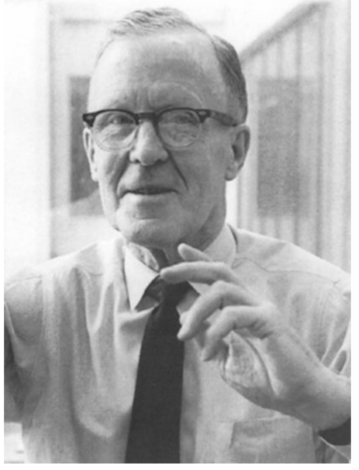


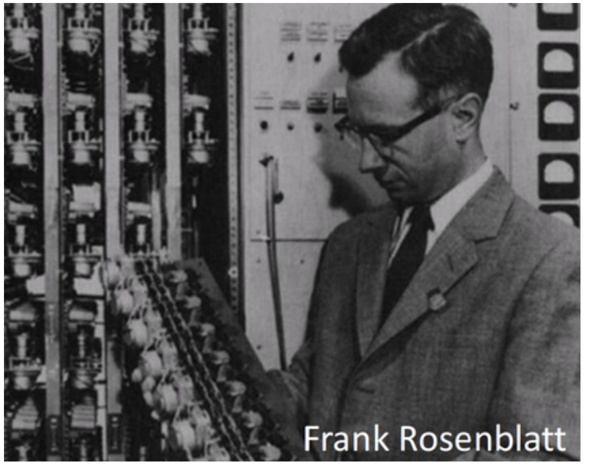
1960



Adaptive Neural Networks

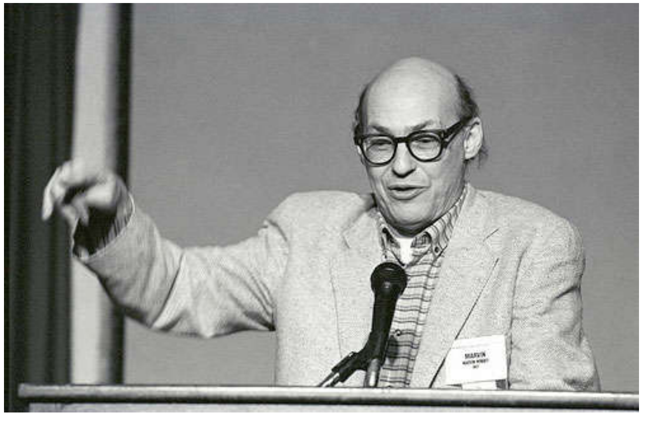
1949

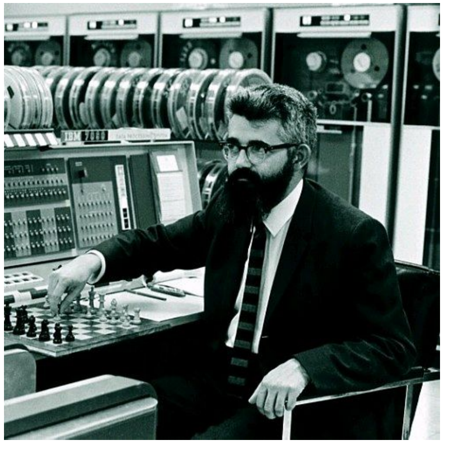




1958

Artificial Intelligence





1959-1960

Miller, G. A. (2003). The cognitive revolution: a historical perspective. *Trends in Cognitive Sciences, 7*(3), 141-144.

The Sloan Foundation had just [1977] completed a highly successful program of support for a new field called 'neuroscience' and … [was] thinking that the next step would be to bridge the gap between brain and mind. …

I lobbied for support of cognitive science, in which six disciplines were involved: psychology, linguistics, neuroscience, computer science, anthropology and philosophy.

I saw psychology, linguistics and computer science as central, the other three as peripheral. …

Each, by historical accident, had inherited a way of looking at cognition and each had progressed far enough to recognize that the solution to some of its problems depended crucially on the solution of problems traditionally allocated to other disciplines.

The Sloan Foundation accepted my argument and a committee of people from the several fields was assembled to summarize the state of cognitive science in 1978, and to write a report recommending appropriate action. The committee met once, in Kansas City. (p.143)

Barbara Partee and I started the Cognitive Science Program at UMass with Sloan Foundation Funding

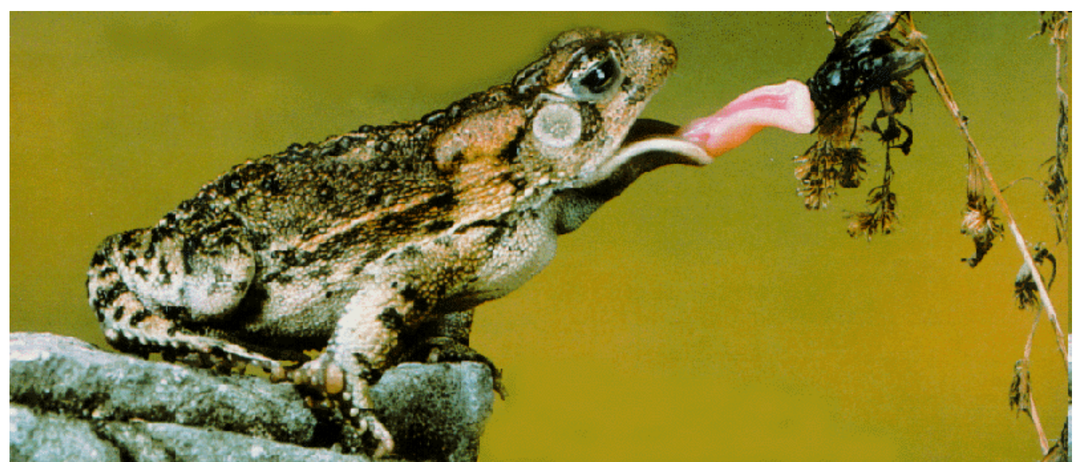
Part 2

Frog's Brains

And this is where the story *really* starts

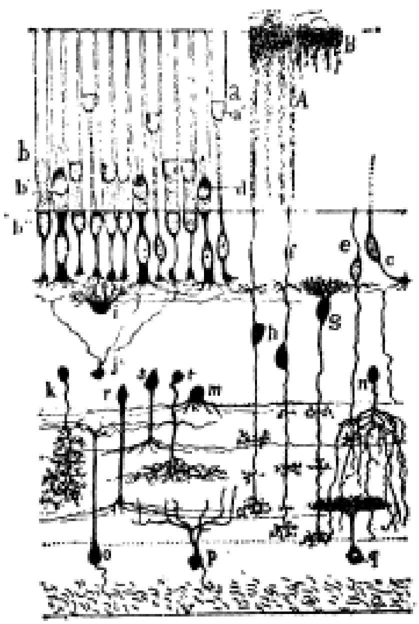
Jerry Lettvin, Humberto Maturana, McCulloch & Pitts (1959)

What the Frog's Eye Tells the Frog's Brain

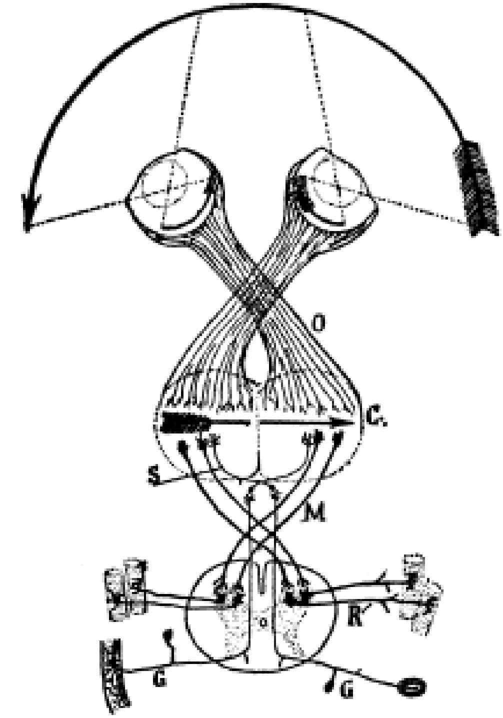


- We have been tempted … to call the convexity detectors "bug perceivers."
- Such a fiber responds best when a dark object, smaller than a receptive field, enters that field, stops, and moves about intermittently thereafter. … Could one better describe a system for detecting an accessible bug?”

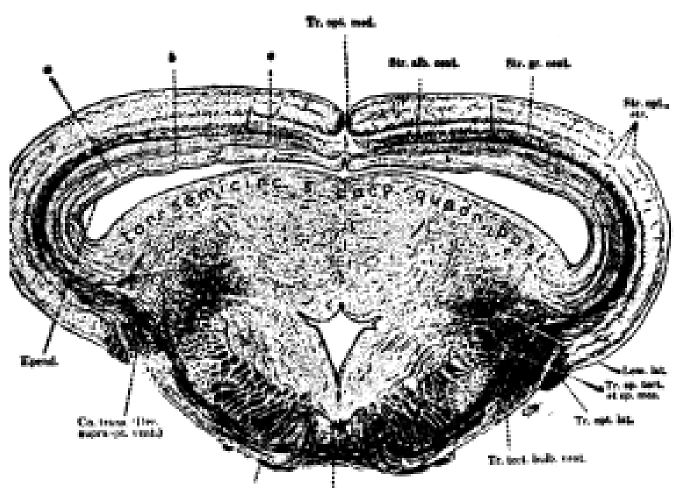
Action-Oriented Perception



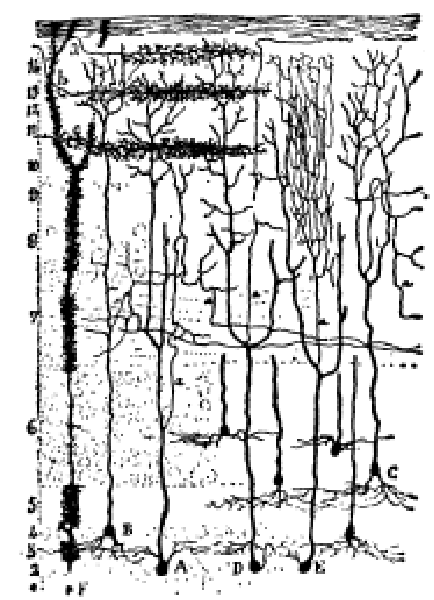
(a)



(b)



(c)



(d)

Contrasting Views

Contrasting views of vision at **Harvard & MIT**

Generic feature extraction (Hubel & Wiesel) *versus*

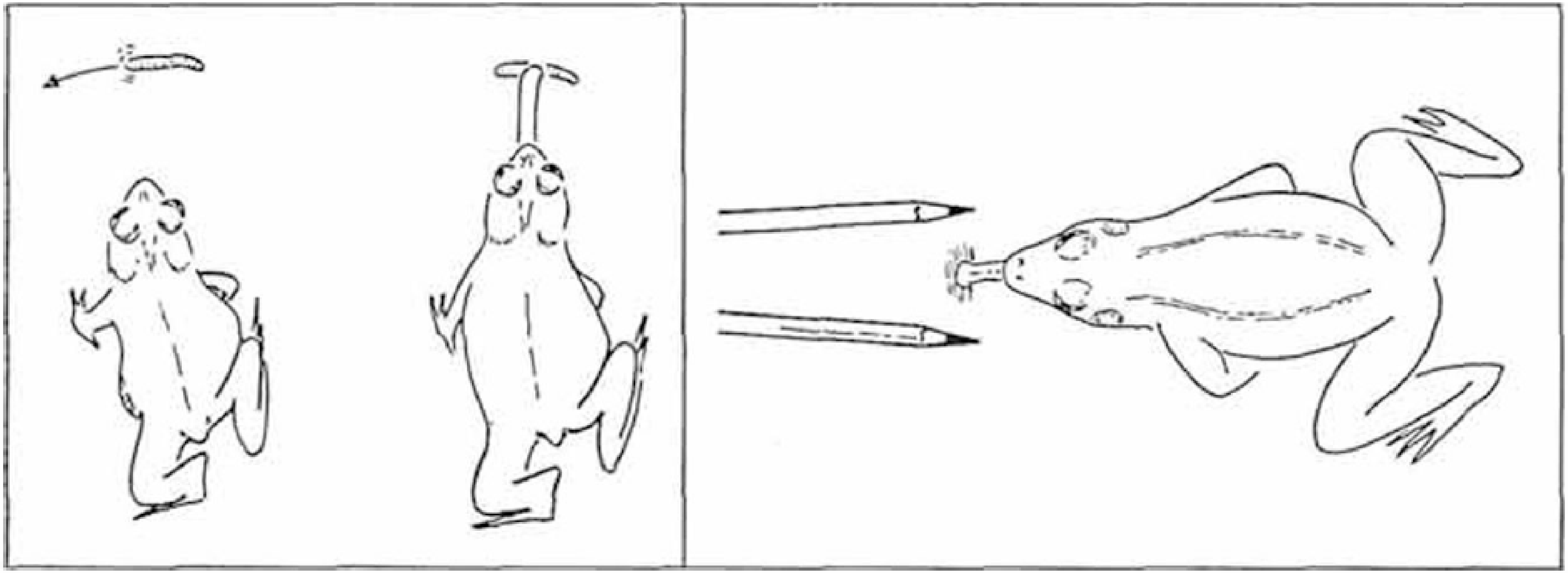
Action-Oriented Perception (Lettvin, Maturana, McCulloch Pitts)

And contrasting motivations for further research:

Neural networks and automata as targets for proving new theorems

Neural networks as biological entities whose roles in brains of diverse species is to be explained

David Ingle (1968): Visual releasers of prey catching behaviour in frogs and toads



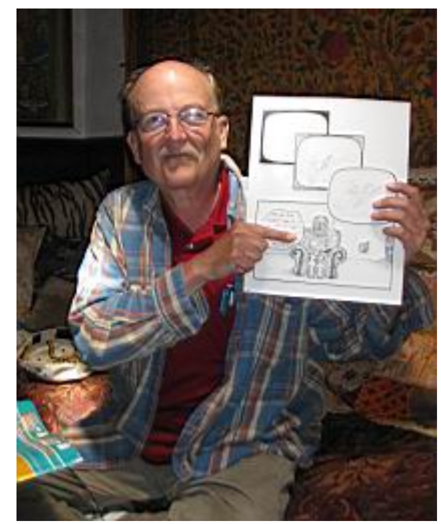
Rana computatrix

Key ***action-oriented*** issue:

What the frog's eye tells *the frog*

Countering the Hubel-Wiesel paradigm

An integrated view of action and perception



With Rich Didday at Stanford (1970 PhD):

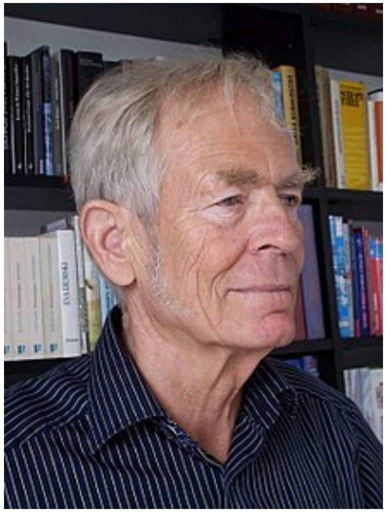
The average fly $\rightarrow$

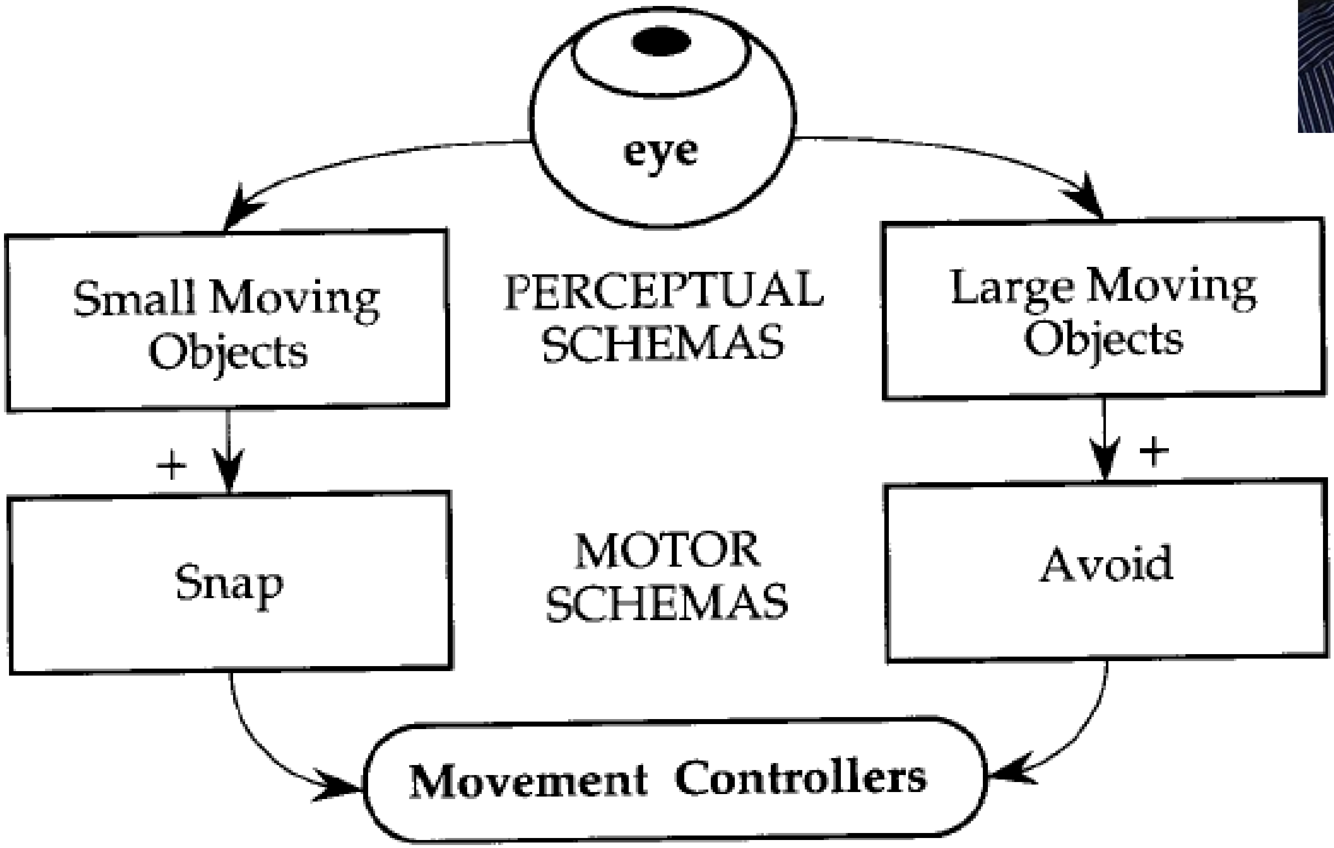
distributed retinotopic computation

Schemas for *Rana computatrix*

Pattern-Recognition in the Toad

Ewert & von Seelen

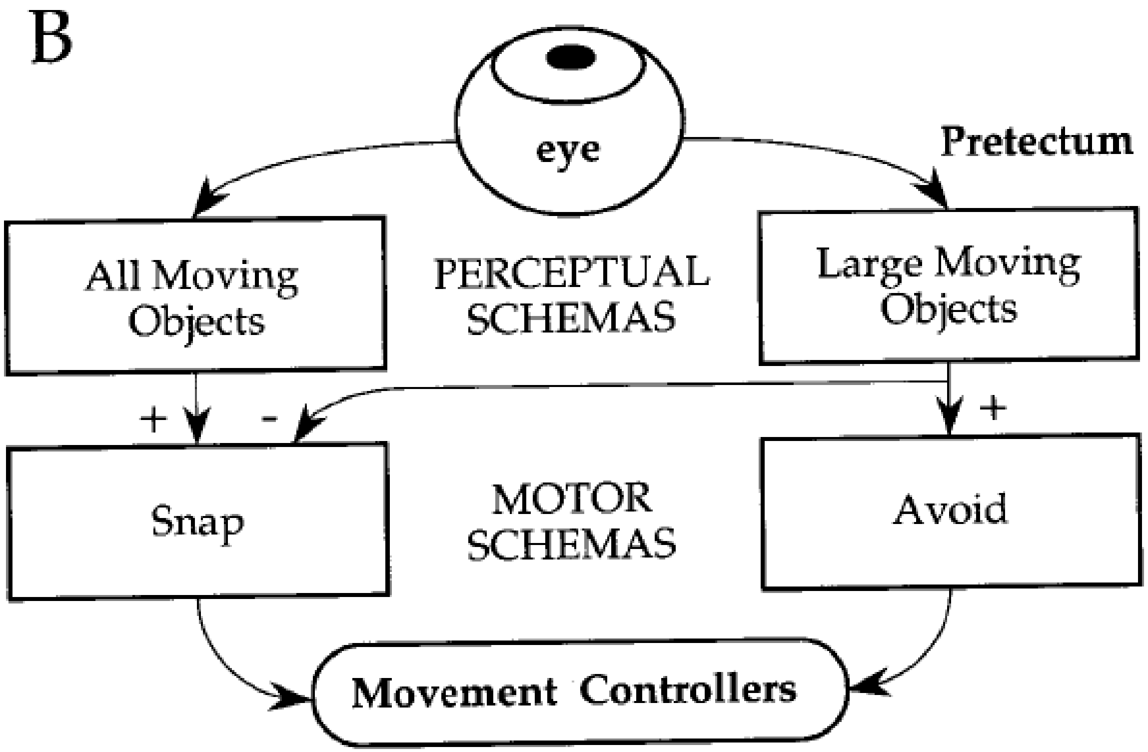




Tectum

Pretectum

Schemas for Pattern-Recognition in the Toad
Ewert & von Seelen



Tectum

Pretectum

Moral: Even gross lesion studies can distinguish between alternative top-down analyses of a given behavior.

Such analyses have been linked to neurophysiological studies

– as well as grounding studies in robotics

A Computational Neuroethology
Behavioral Responses to Moving Objects

Prey

First produces orienting, followed by approach (if sufficiently far), then snapping (amphibia) when within striking distance.

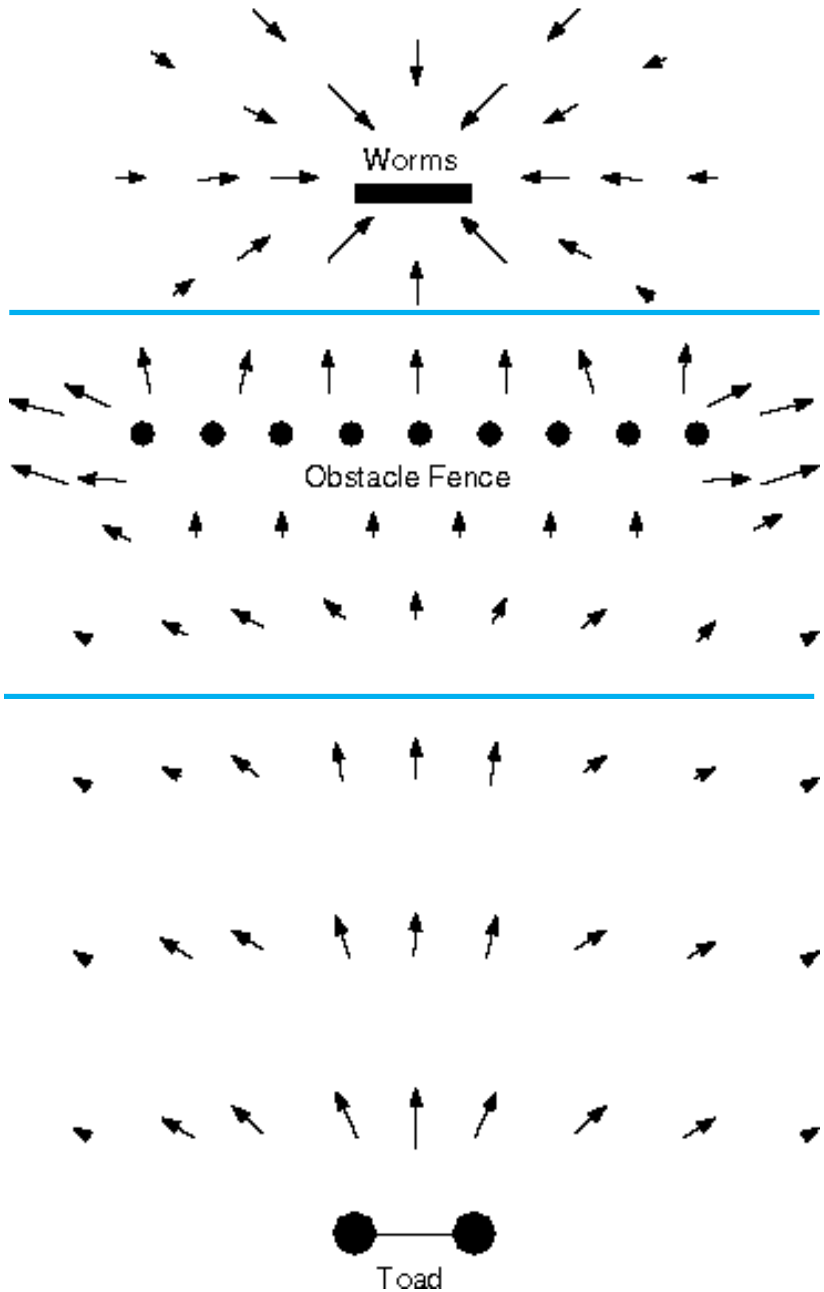
Predators:

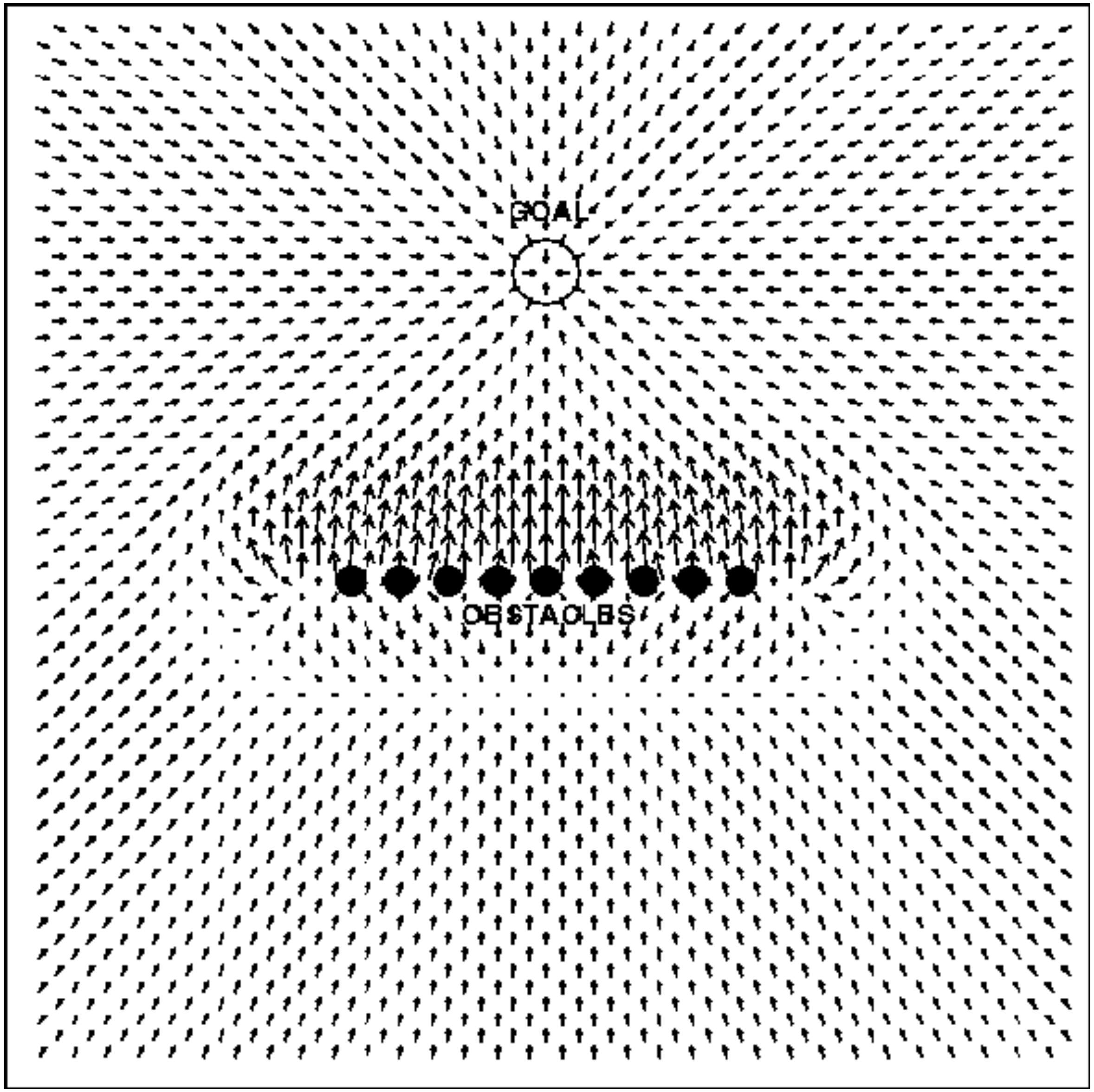
Produce several avoidance behaviors, for example, a large flying stimulus yields ducking behavior

Detour Behavior

Negotiating obstacles while approaching prey or avoiding predators

Potential Fields for the Control of Action





Rana Computatrix: Computational Neuroethology

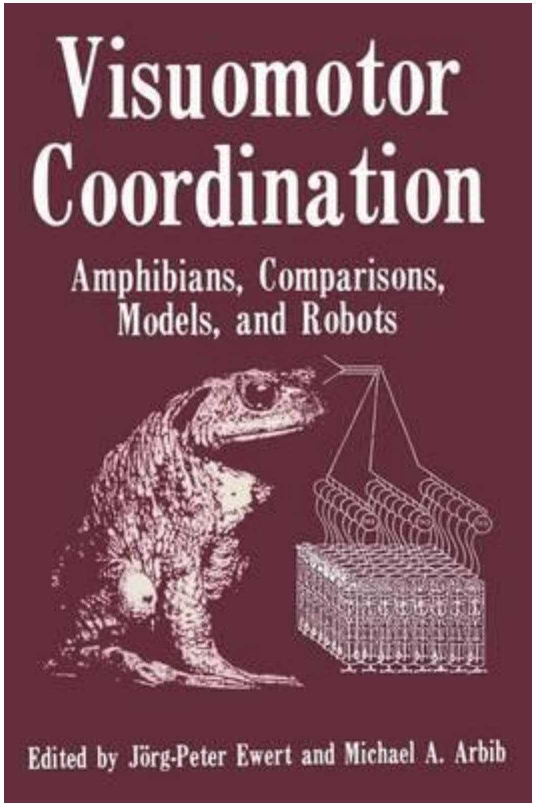
Worms and Anti-Worms
Rolando Lara
Francisco Cervantes-Perez
DeLiang Wang

Depth and Detours
Donald House
Hyun-Bong Lee
Mathew Lamb

Controllable MPGs and Schema-Based Learning
Jim-Shih Liaw
Fernando Corbacho

Retina
Yill-Byung Lee
Jeff Teeters

Spin-off: Frog-inspired mobile robots
Ron Arkin



Part 3

From Hand to Language

An Action-Oriented/Schema-Theoretic Approach to Language

An early payoff from the Cognitive Science Program at UMass:

Arbib & David Caplan: Neurolinguistics must be computational (BBS 1979)

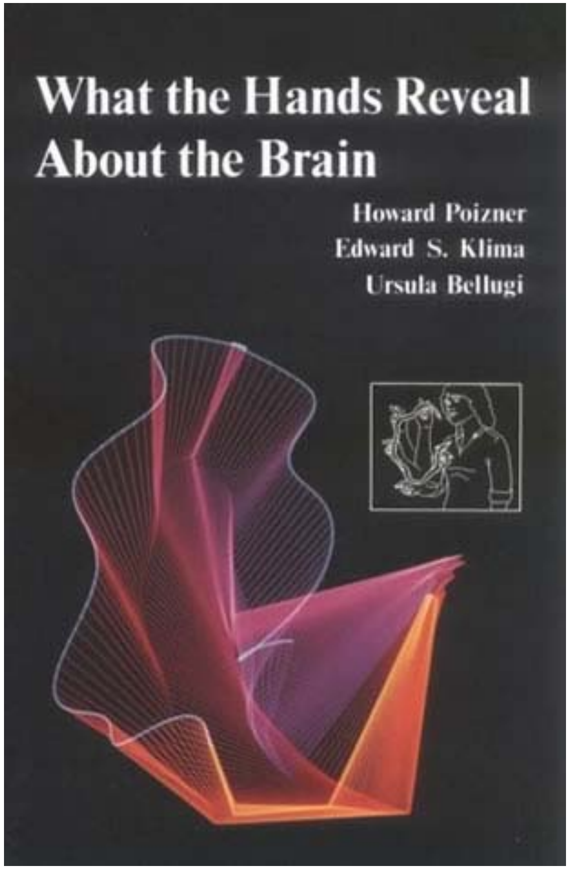
A cooperative computation/schema-theoretic approach:

Interacting brain regions support language

Embedding language mechanisms in a framework of **action-oriented perception**

1985-86: A Sabbatical at UCSD
The Cognitive Science *Program*
but it was USC that hired me ...

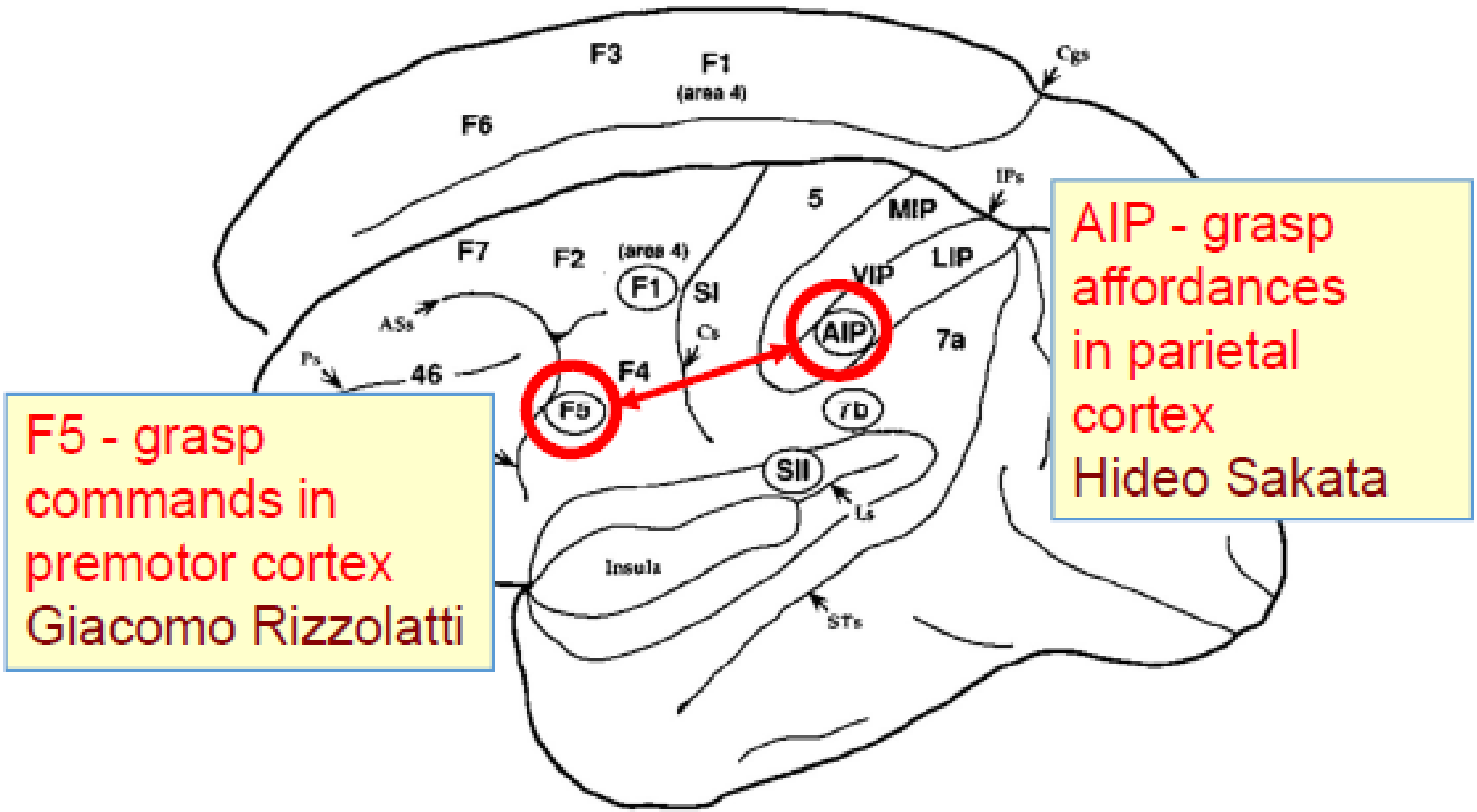
Ursula Bellugi at the Salk Institute



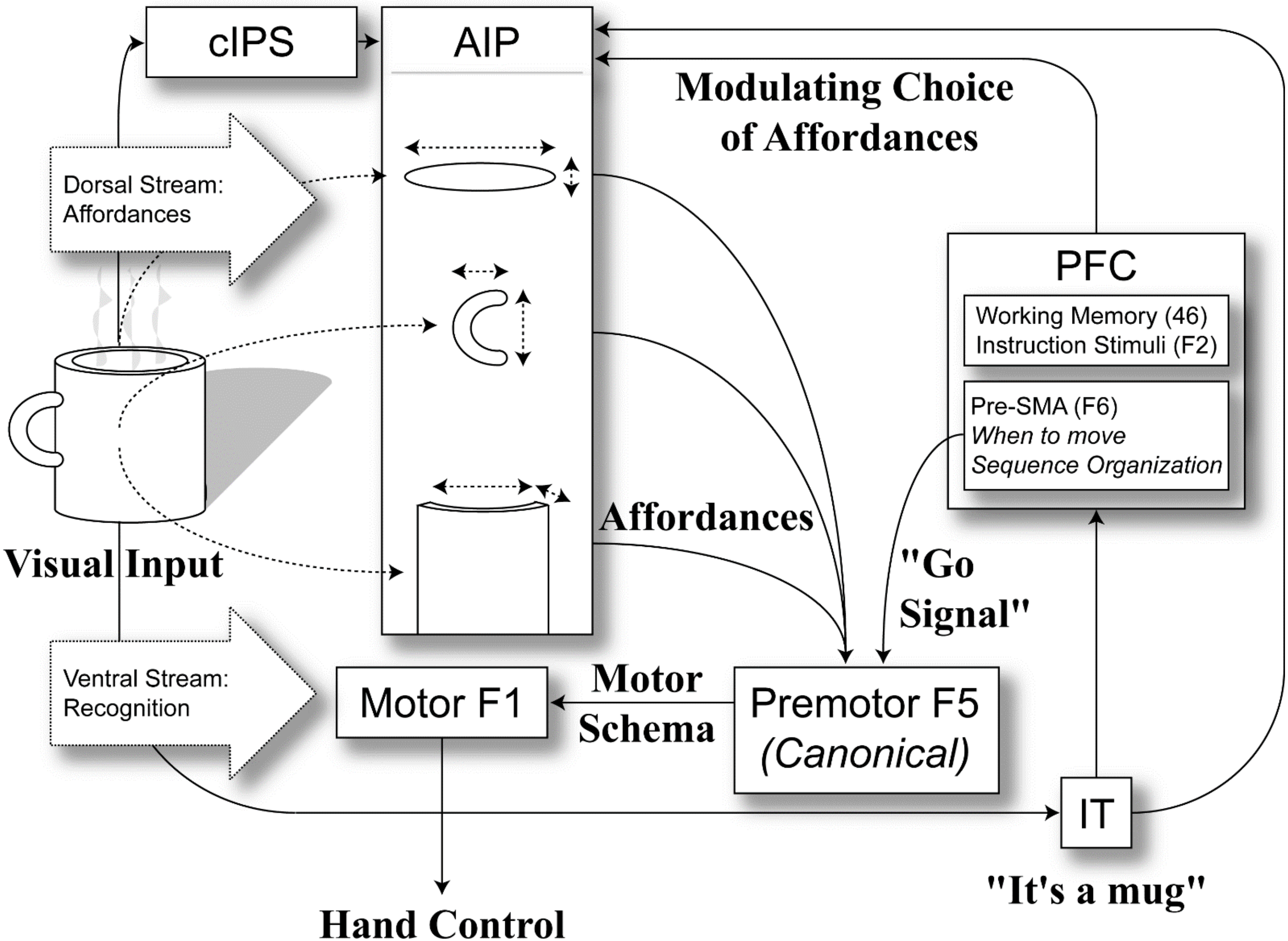
Visual Control of Grasping

A recurrent theme in the analysis of sensorimotor coordination:

parietal affordances → frontal motor schemas

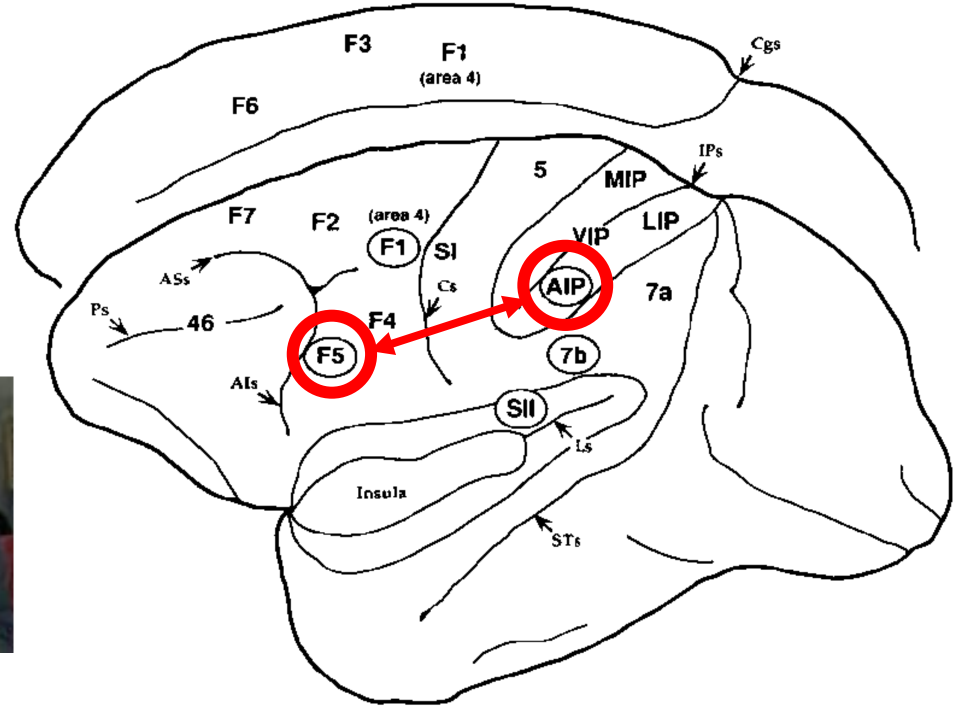


The FARS Model:
Dorsal and Ventral Paths in the control of grasping



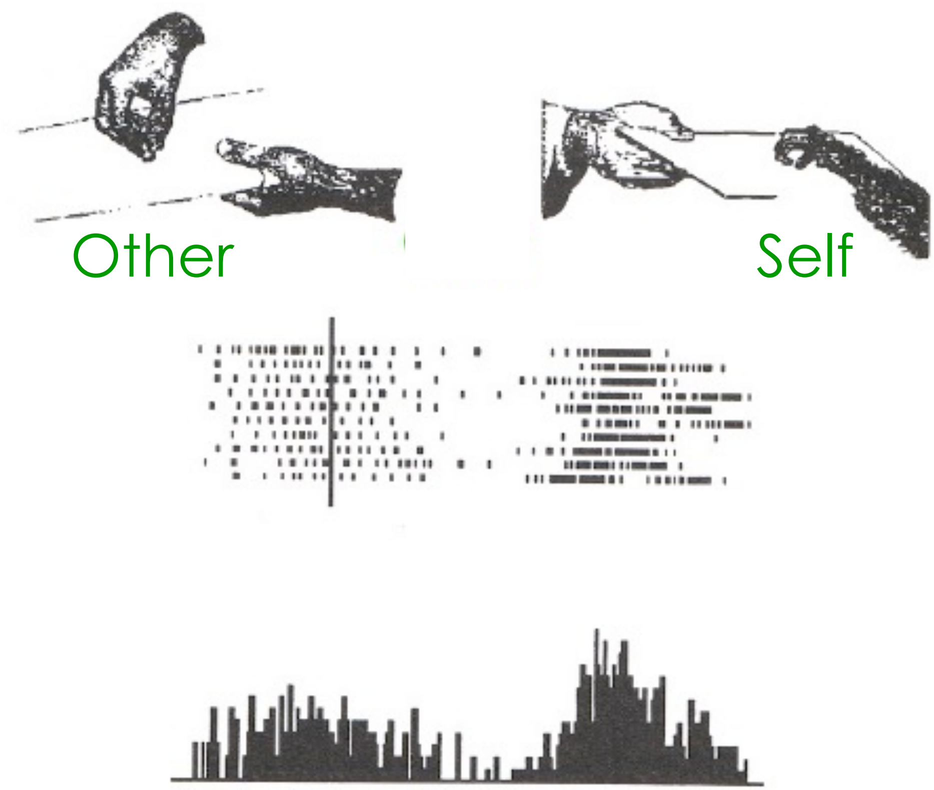
Mirror Neurons

di Pellegrino, G., Fadiga, L., Fogassi, L., Gallese, V., & Rizzolatti, G. (1992). Understanding motor events: a neurophysiological study. *Exp Brain Res*



1) Action-related F5 neurons may fire most strongly for a specific phase of the action.

This example: a precision pinch



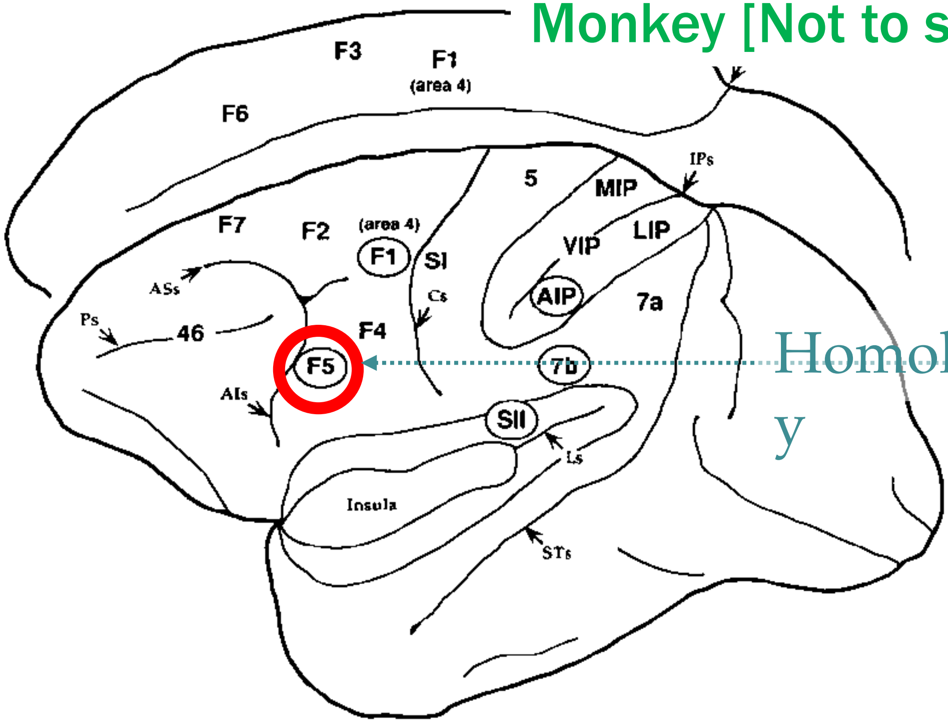
2) A mirror neuron is active for ***execution*** of a limited set of actions & ***observation*** of a (strict or broadly) congruent set of actions

3) *A* canonical neuron in F5 fires when the monkey executes an action but not when observing it

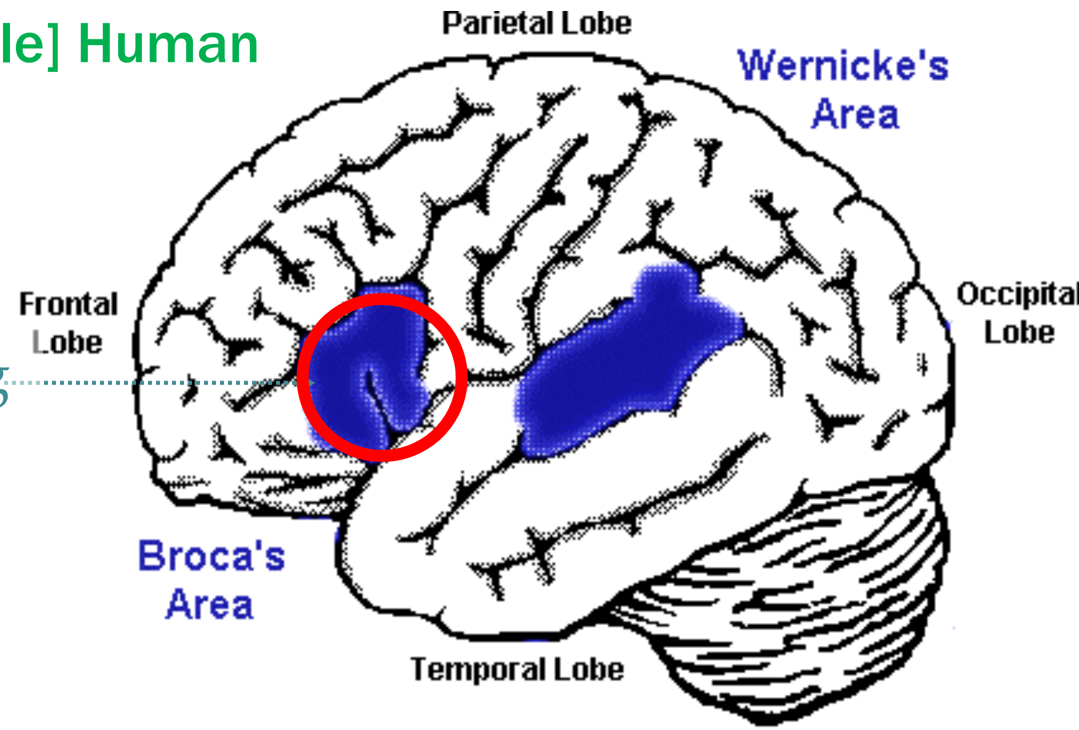
Language Within Our Grasp

Rizzolatti and Arbib, TINS, 1998

Monkey [Not to scale] Human



Homology

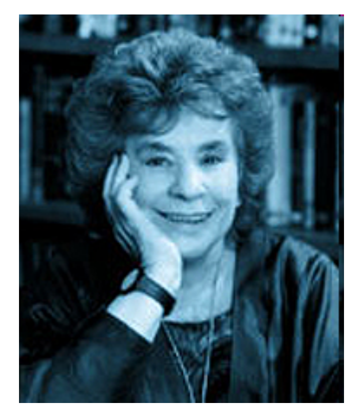


Key data bring language back to "active status" after a 12 year inter-regnum:

- Monkey F5 (with its mirror system for grasping) is homologous to Brodmann's area 44 in human Broca's area
- Imaging studies show activation for both grasping and observation of grasping in or near Broca's area

Language is a Multi-Modal System: Face, Hands, and Voice ....

Ursula Bellugi



Extending the Mirror System Hypothesis
EvoDevoSocio

Pre-Hominin

grasping

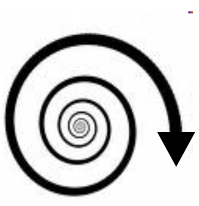
mirror system, matching action observation and execution for grasping

Shared with LCA-m: last common ancestor of human and monkey

simple imitation system for grasping

Shared with LCA-a: last common ancestor of human and great apes

Hominin Evolution



a **complex imitation and action recognition system**

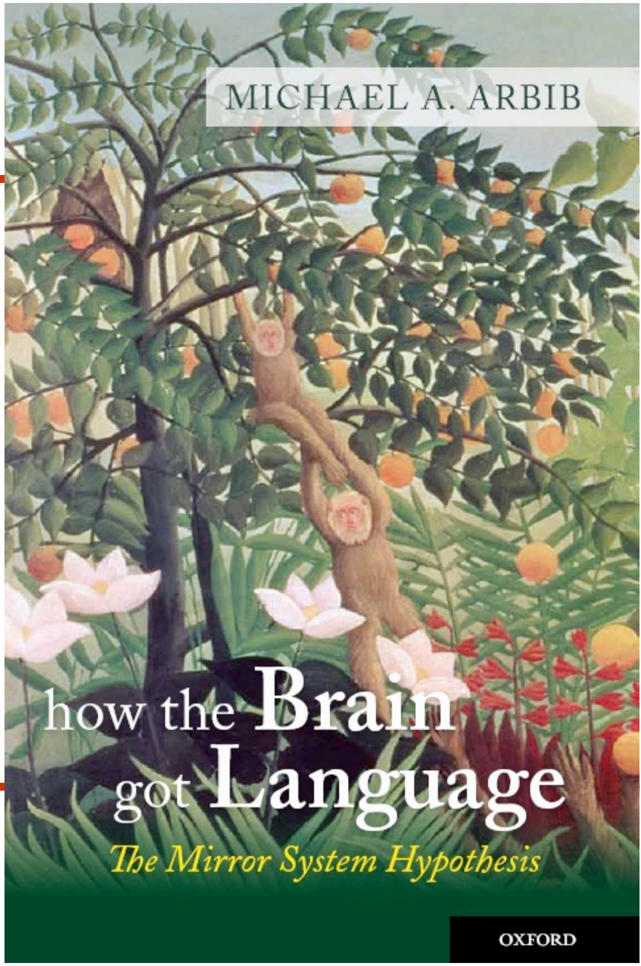
protosign: a manual-based communication system, breaking through the fixed repertoire of primate vocalizations to yield an open repertoire

protospeech: resting on the "invasion" of the vocal apparatus by collaterals from the communication system based on F5/Broca's area

Cultural Evolution in Homo Sapiens

language: from action-object frames to syntax and a compositional semantics:

Co-evolution of cognitive & linguistic complexity



2012

Modeling & Neuroinformatics

Mirror neuron learning

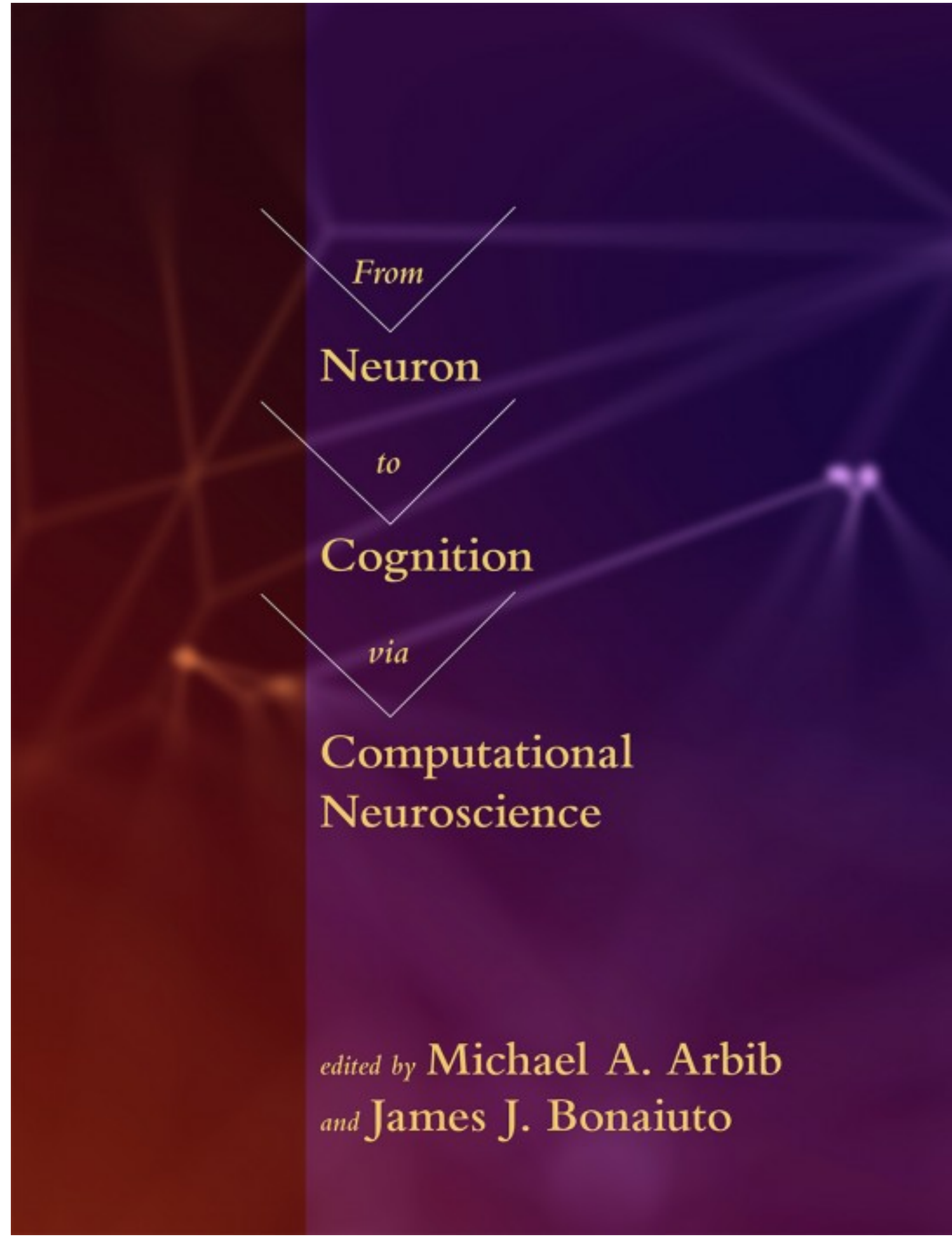
Integrated learning of grasps and affordances

Sequence learning in macaques

Dyadic brain modeling: Apes acquiring gestures through ontogenetic ritualization

Template construction grammar for linking language to "what it is about"

BODB: The Brain Operation Database



2016

How the Brain Got Language: Towards a New Road Map

Workshop in La Jolla: August 29-31, 2017

Interaction Studies, 19(1-2). Special double issue In Press

21 papers by contributors

Michael A. Arbib; Francisco Aboitiz; Judith M. Burkart; Michael Corballis; Gino Coudé; Erin Hecht; Katja Liebal; Masako Myowa-Yamakoshi; James Pustejovsky; Shelby Putt; Federico Rossano; Anne E. Russon; P. Thomas Schoenemann; Uwe Seifert; Katerina Semendeferi; Chris Sinha; Dietrich Stout; Virginia Volterra; Sławomir Wacewicz; and Benjamin Wilson

plus

The Comparative Neuroprimatology 2018 (CNP-2018) Road Map for Research on How the Brain Got Language

Part 4

Buildings

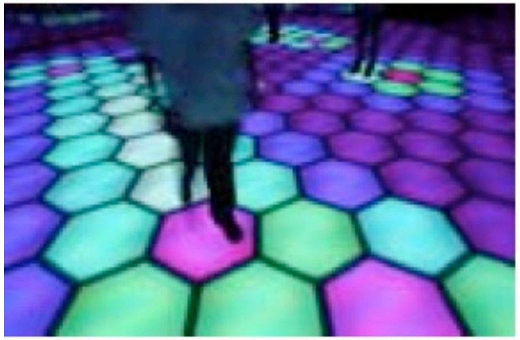
The Neuromorphic Design & Functionality of the Interactive Space 'Ada'

Rodney Douglas, Paul Verschure & Colleagues designed ADA as a pavilion at the Swiss National Exhibition of May - October, 2002. ADA had over 550,000 visitors

Ada's sense of touch

Ada's "skin" (floor) serves as both sensor system and communications organ

Its play with light allows Ada to "communicate."



Behaviors & Interactions

A natural progression in visitor interaction:

Sleep	One tile color for all visitors
Wake	Visitors given different-colored floor tiles
Explore	Probe for “interesting” visitors; deploy light fingers and gazers
Group	Try to direct visitors to a certain location in space
Play	Play game selected on basis of number of visitors in space
Leave	Tile effects show path to exit of space for each visitor

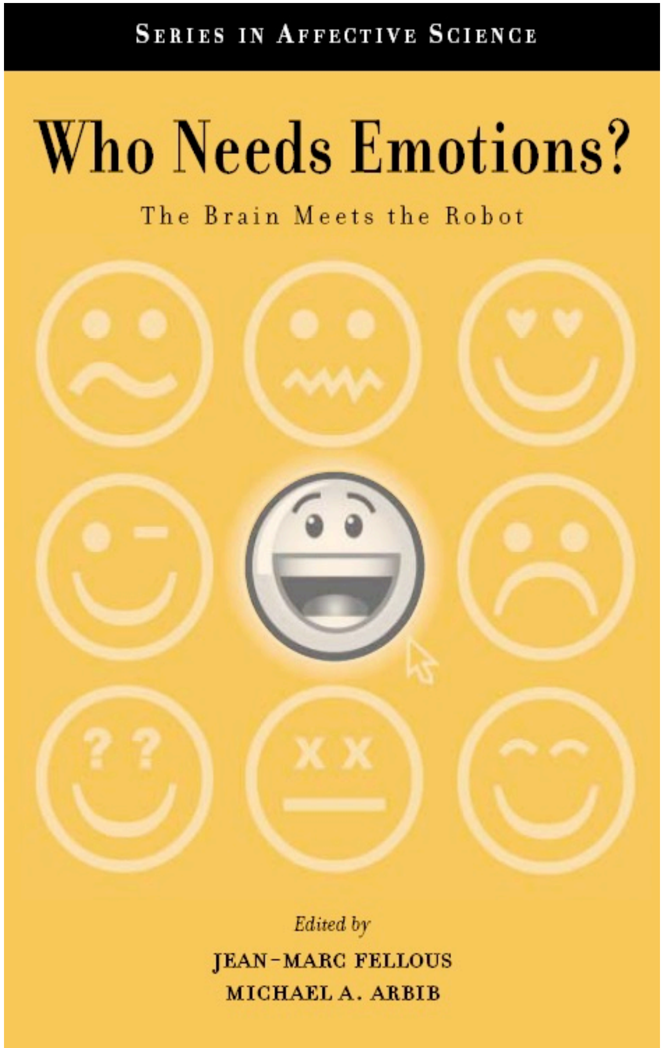
Emotions in a Neuromorphic Architecture

Ada “wants” to interact with people

When people participate, she is happy

When they do not, she is frustrated

Ada's level of overall happiness is translated into the soundscape and the visual environment in which the visitor is immersed, establishing a closed loop between environment and visitor

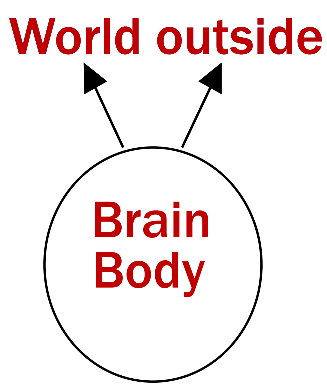


(OUP 2005)

From Neuroethology to Neuromorphic architecture: Interactive Infrastructures (“Brains”) for Buildings

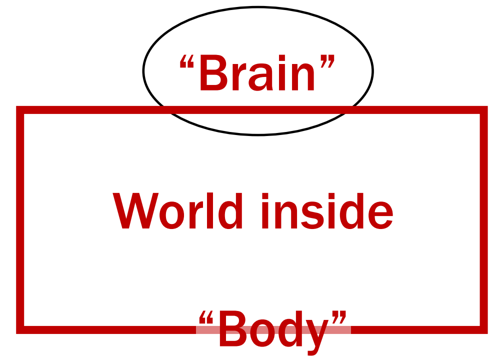
The Brain of the Animal

moving sensors
to achieve a viewpoint



The interactive infrastructure of the Room

interacting with those within



From computational modeling of the brains and bodies of animals (including humans) as they interact with the physical *and social* environment

To the design of interactive infrastructure as part of a building to more effectively meet the needs of its occupants

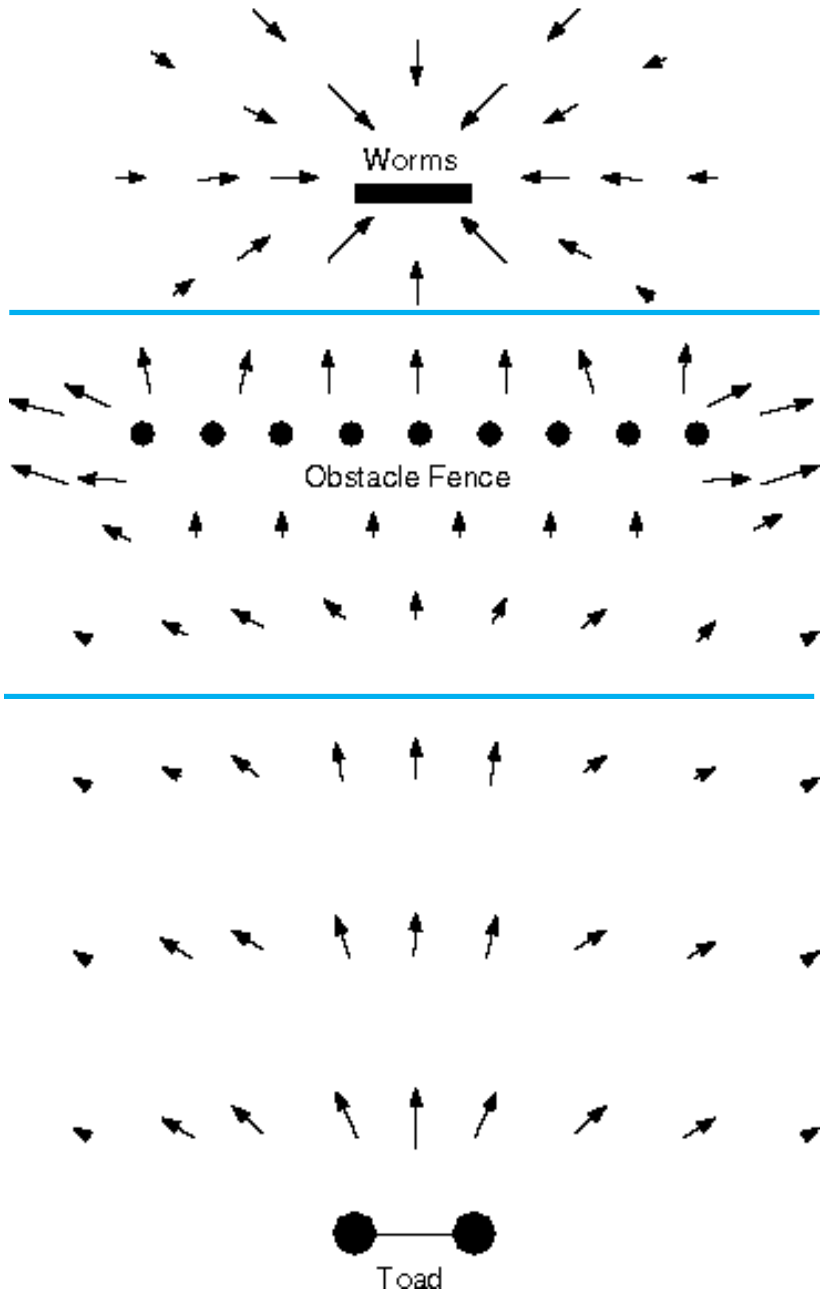
3 Ways to Link Architecture and Neuroscience

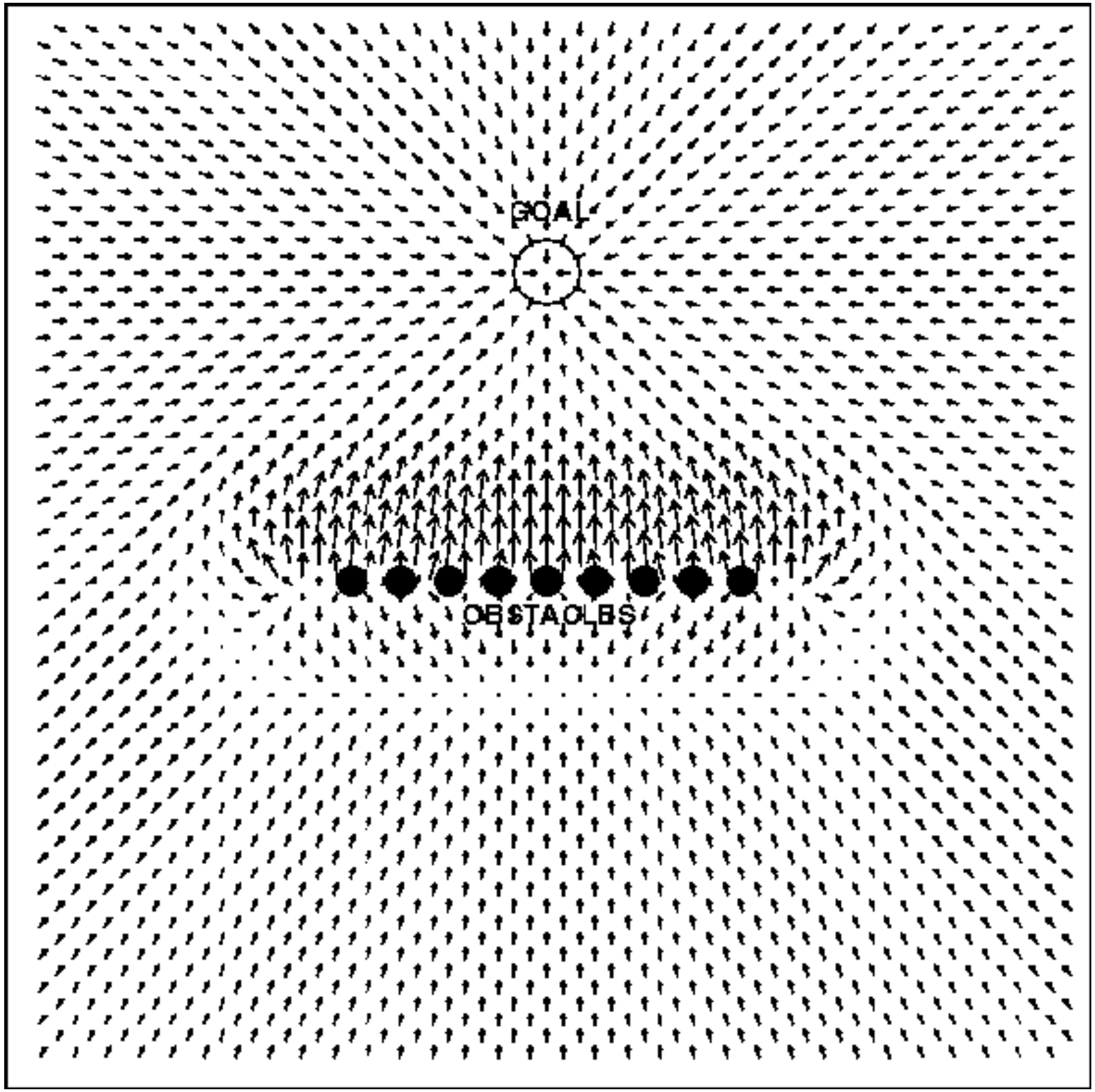
Neuroscience of the design process

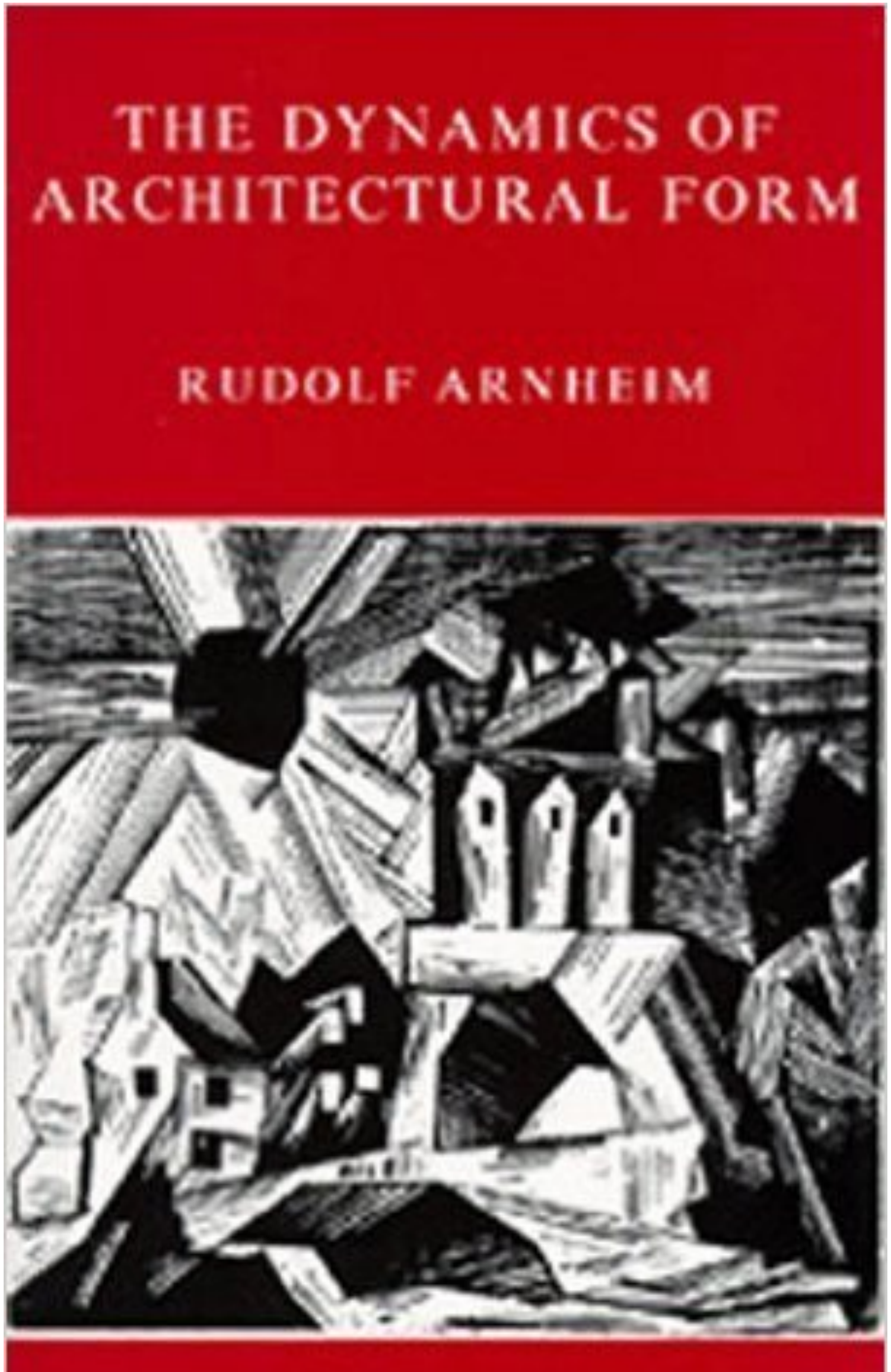
Neuromorphic architecture

Neuroscience of the experience of architecture

Modeling the Frog







As you look at a building, how do the different parts relate.

What does the psychology of vision tell us about architecture.

A non-action-oriented view

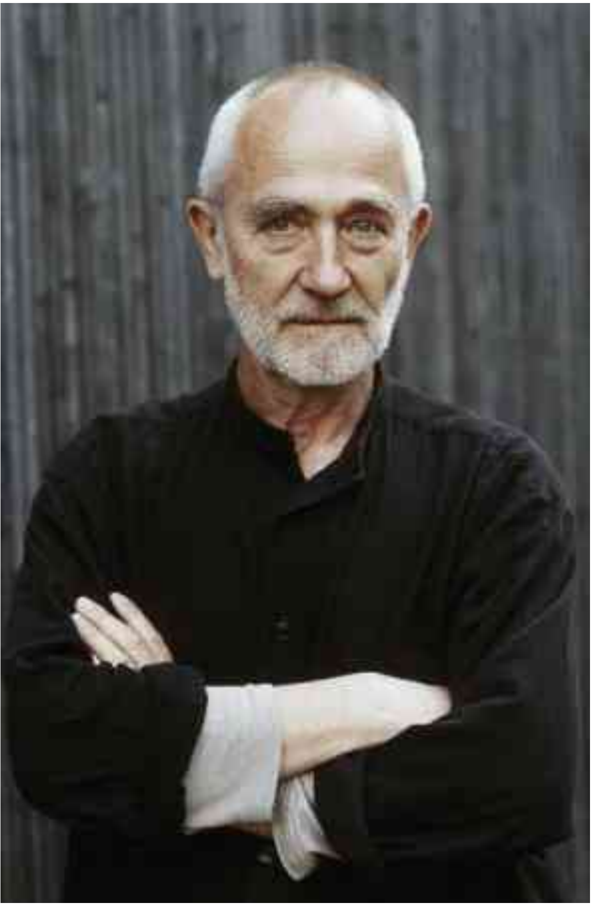
When Le Corbusier was designing the Carpenter Center for the Visual Arts at Harvard University

- it was realized that the horizontal protrusion of the large curved North Studio on the second floor would lose much of its outward thrust unless a larger space beneath it rendered it more independent of the attraction exerted by the ground.
- For this reason an essentially unfunctional pit was dug beneath the studio area, which, resting on relatively slim pilotis, acquired thereby the necessary dynamic freedom

http://tenivision.tumblr.com/post/40548240954

Vals, Switzerland
Peter Zumthor

Peter Zumthor's *A Way of Looking at Things*



When I design, I frequently find myself sinking into old, half-forgotten memories .... Yet, at the same time, I know that all is new ...

Construction is the art of making a meaningful whole out of many parts.

The challenge of developing a whole out of innumerable details, out of various functions and forms, materials and dimensions.

The Future of Memory: Remembering, Imagining, and the Brain

Memory supports adaptive functioning:

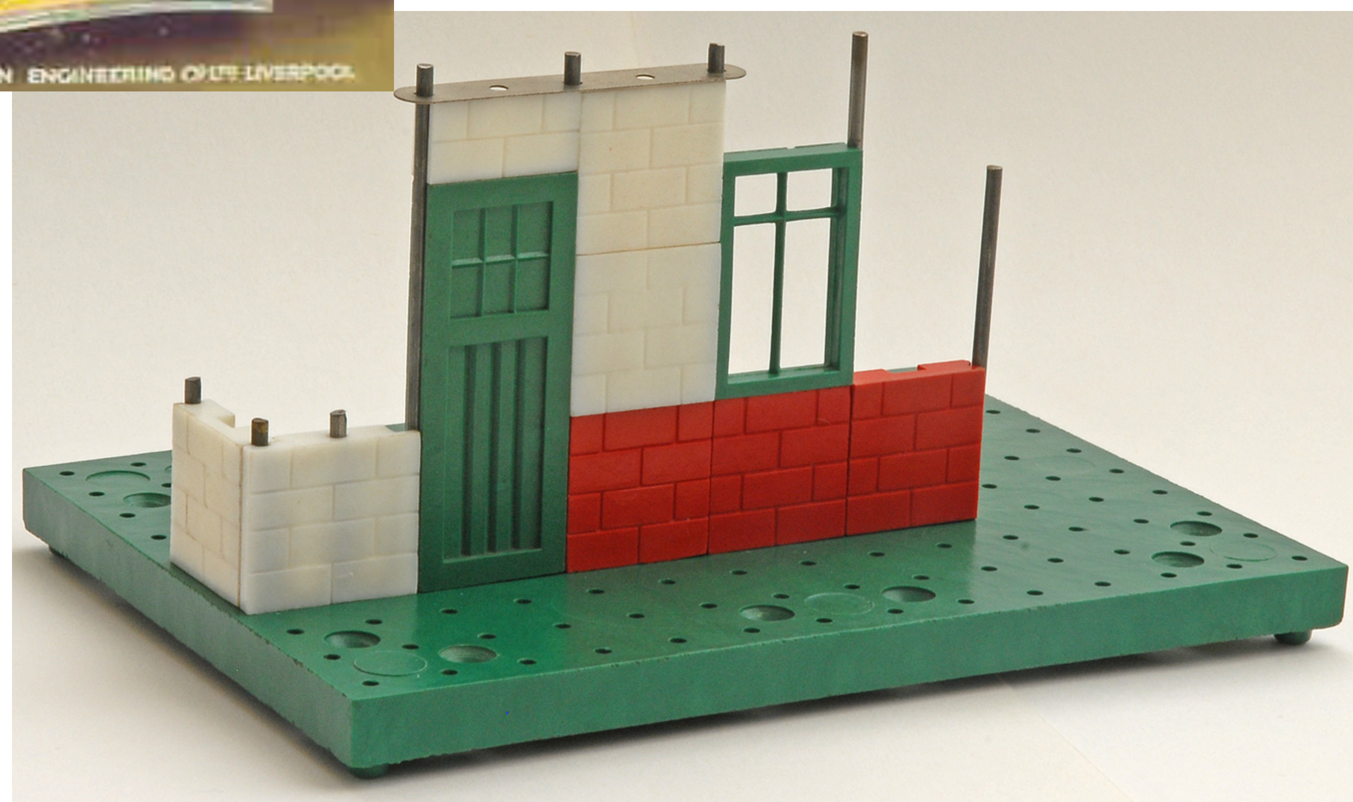
There are striking similarities between remembering the past and imagining or simulating the future – and a common brain network underlies both memory and imagination.

But there are differences in brain activity between remembering the past and imagining the future

How might these findings carry over to “imagining a new building”?

Current Research Challenge: To better understand the distributed structure of memories that supports their role in imagination

A Language for Buildings?



Is Architecture a Language?

Language

Using the constraints of grammar to put words from the lexicon together in new ways express new meanings built atop the prior meanings of each word

Architecture as a Design Process

Each design may lead to the discovery/invention of new “building blocks” (a changing “lexicon”) and new forms of construction (a changing “grammar”)

Once the Building Exists

The building provides the affordances; each inhabitant may explore them to create their own “meanings.”

For more linkages between neuroscience and architecture

7 UCSD Lectures

YouTube
"Arbib Architecture"

arbib@usc.edu