robots for brains

or

embodiment versus envatment

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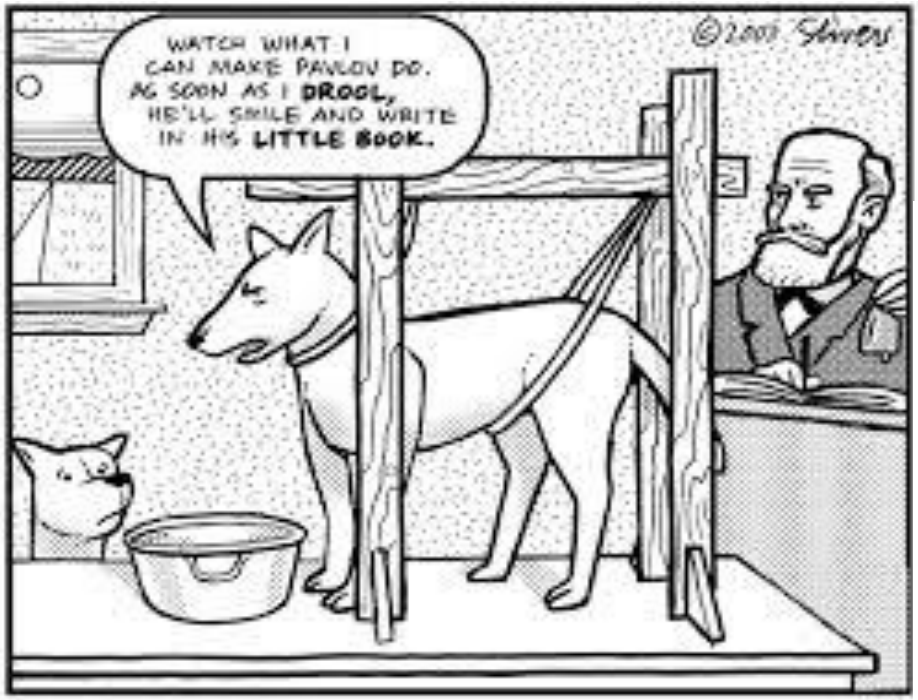
Pioneering research and skills

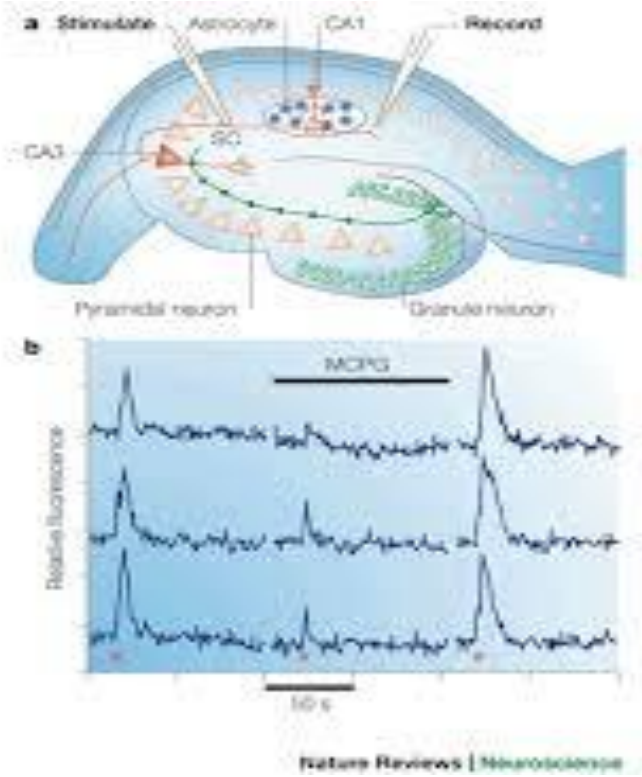
Overview

Do the new technological advances blending biological beings with computational systems shed light on how to instantiate mind in computing devices?

- Can robotics offer anything for brain sciences?
- Intentionality in computational systems?
- Cognitive robotics – an answer?
- Modern embodiments – do they escape CRA?
- Conclusions

classical paradigm - open loop stimulation





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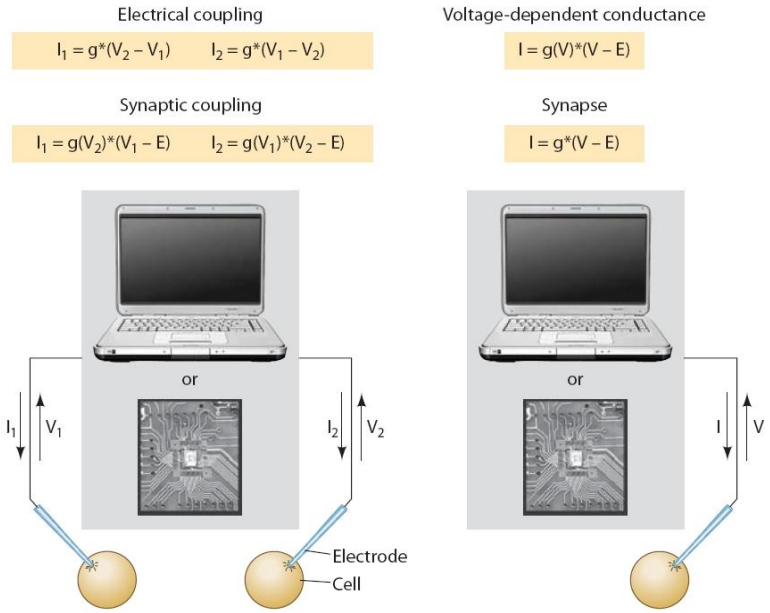
closed loop paradigms

- **dynamic clamp**



Andrew Schwartz, U Pitt

- Brain Machine Interfaces
  - Invasive

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interactions with external world

•what about intentionality?

Cognitive robotics

- Significant departure from GOFAI
- Rapidly aligning with embodied cognition and enactivism providing foundational grounding in modern cognitive science

Does the modern cognitive robotics (computational system embedded in artefactual body) escape then the CRA?

- Enactivism – two interpretations
  - Cognitive robotics is particularly aligned with one

"our ability to perceive not only depends on, but is constituted by, our possession of ... sensori motor knowledge"

(Noe , 2004)

Cognitive robotics

- Eschewes Varelian enactivism related to his neurpohenomenology (and hence autopoiesis)

it is somehow intuitive that cognition relates to sensorimotor interactions rather than to material self-constructing processes

(Barandiaran and Moreno, 2006)

- Emphasis on sensory motor couplings
- Embraces Gibbsonian affordances

"a pattern in the structure of sensorimotor contingency"

"for perceptual sensation to constitute experience – that is, for it to have genuine representational content – the perceiver must possess and make use of sensorimotor knowledge."

(Noe , 2004)

The Emperor's new robots?

- why "*a pattern in the structure of sensorimotor contingencies*" is any different from "*patterns in sensory data*"?
- Sensory motor coupling:
  - Either
    - (A) "correlations" between two types of neural activity (motor action) (sensory activation)
      - » No different from correlations between two types of neural sensory activity (sensory activation X) (sensory activation Y)
  - Or
    - (B) Extra 'ingredients' present
      - » bio-physico-chemical properties of the body induced by motor actions
  - Current cognitive robotics offers (A) only

The Emperor's new robots?

- Concentrates exclusively on grounding in the external world
  - Can capture the relational structure of the external world
  - Correlations and look-up tables can do that
  - bad news for hungry Searle in CRA!
- Adding more sensors (eg touch, proprioception) and actuators does not buy anything
  - Larger vectors to correlate (larger lookup tables)
- Neither does formalism (symbolic, dynamical, connectionist)
  - Simply different forms of capturing structure of the external world
  - No formalism has inherent intentionality
  - implementational invariance
  - hence no drives to seek "patterns in the structure of sensorimotor contingencies"
- Very important but not fundamental for intentionality

The real deal

- In contrast, real cognitive agents have internal drives at all levels of organisation – survival, metabolic and physical - that make them act in the world, make them react to the external disturbances (information) and manipulate it in such a way that they will support immediate and delayed fulfilment of the drives at all levels.

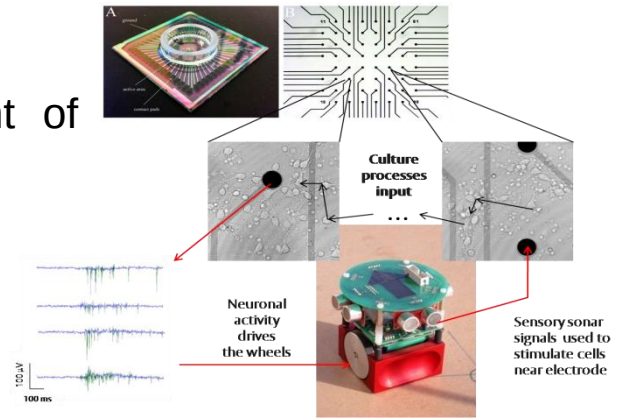
- The intentionality comes not only from the potential mapping between the relational structures of the external world and the states of biological constituents; it requires relating such structures to internal drives and needs of an agent

- Systems which are based on formal manipulation of the internal representations are thus neither intentional nor autonomous as no manipulation is internally driven nor serves intrinsically meaningful purpose other than that of system designer's.

Modern embodiments

•Animat

•Robotic Embodiment of Neuronal Culture



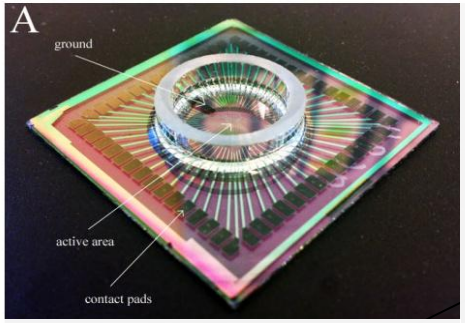
Types:

- Sentient being driven
  - Prostheses, implants, BMI, BCI
- Formal system driven
  - Animats

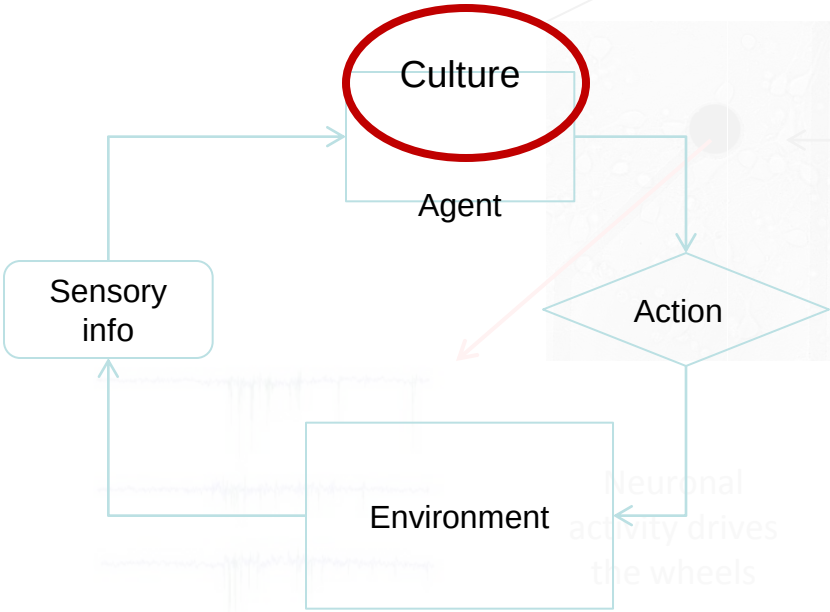
- From intuition pump to physical realisation of thought experiment

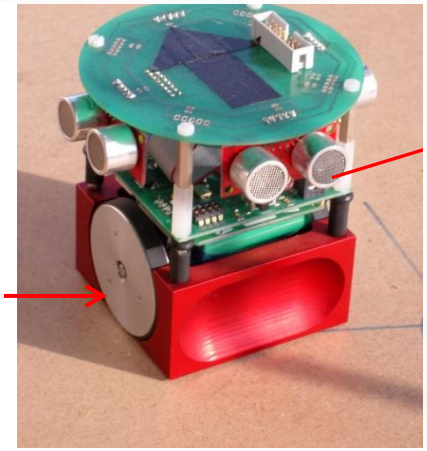
"*Suppose that a team of neurosurgeons and bioengineers were able to remove your brain from your body, suspend it in a life-sustaining vat of liquid nutrients, and connect its neurons and nerve terminals by wires to a supercomputer that would stimulate it with electrical impulses exactly like those it normally receives when embodied.*"

(Cosmelli, Thompson, 2011)



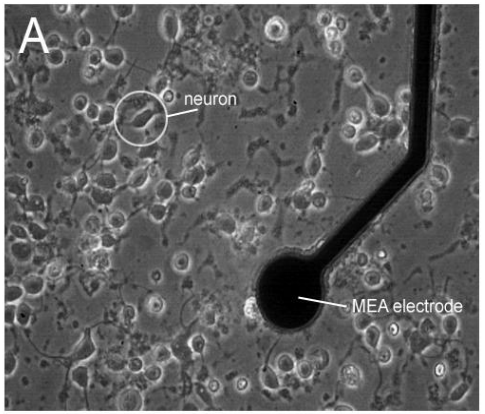
- *Understanding information processing in the culture*
- *Perceived 'state'*



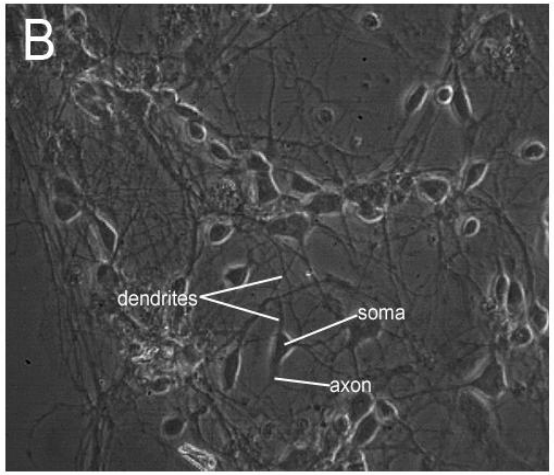


•Role of closed loop in state formation and evolution

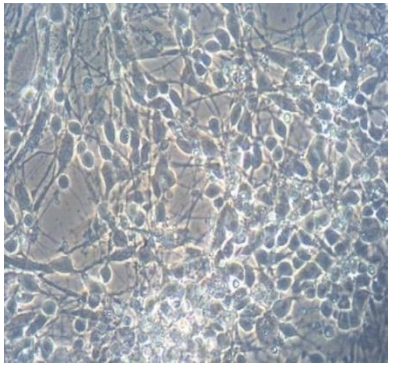
Cultures



- 2D monolayers
- neurons and glia
- Cell density (10-20k/mm2)
  - Inhomogenous
- Restricted to the recording area (with help)



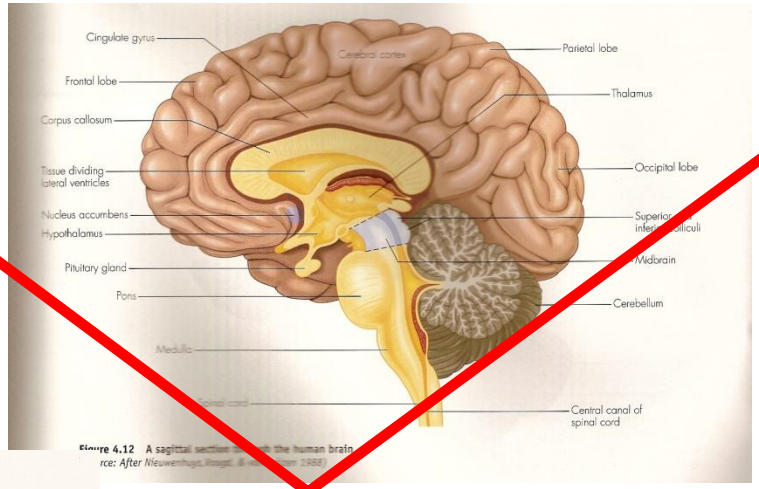
- Connectivity
  - Random
- Activity
  - Irregular
  - Bursting
  - Indicative of complex, recurrent interactions



•Identification of culture capacity

- •Cholinergic system
- •Temporal dynamics of activity
- •Functional connectivity
- •Complex Networks Evolution

No familiar structure



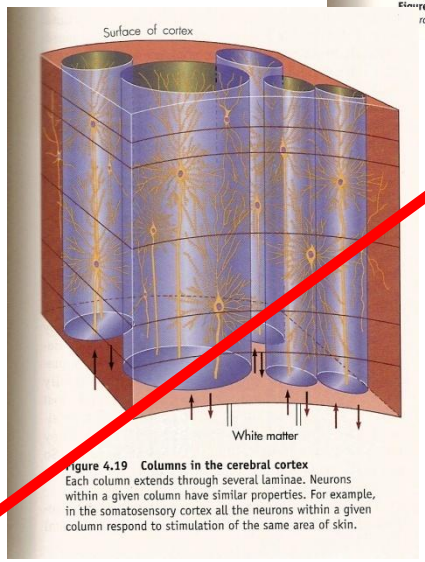
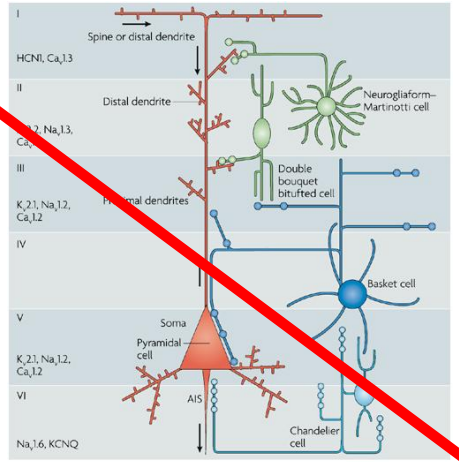
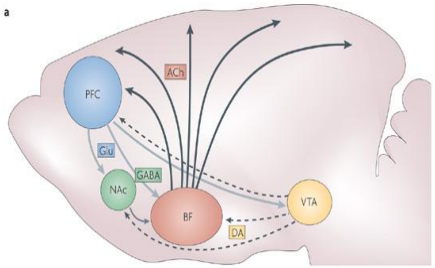


Figure 4.19 Columns in the cerebral cortex
Each column extends through several laminae. Neurons within a given column have similar properties. For example, in the somatosensory cortex all the neurons within a given column respond to stimulation of the same area of skin.

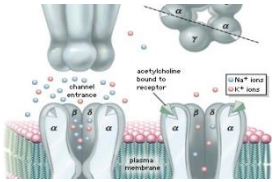


Cholinergic system

in vivo



Sarter et al, 2009



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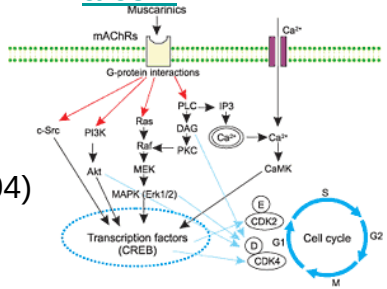
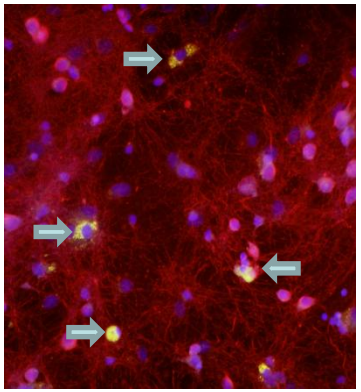


(Ma et al, Drug News Perspect 2004)

- Widespread cortical innervation from Ach neurons in basal forebrain
- Involved in control of blood flow (metabolic regulation)
- modulation of sensory information flow
  - Working memory
  - Attention

in animat



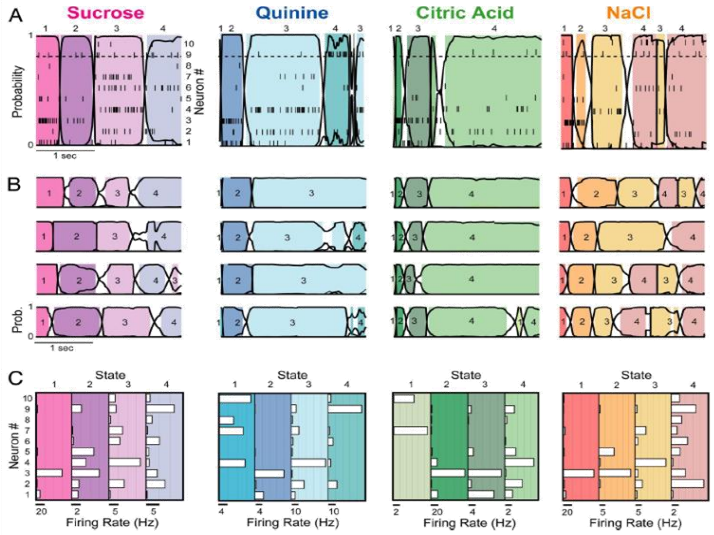
•Functional nAchR and mAchR

•presence of Ach producing neurons

•neuromodulatory Ach role consistent with *in vivo*

Meta-stable states

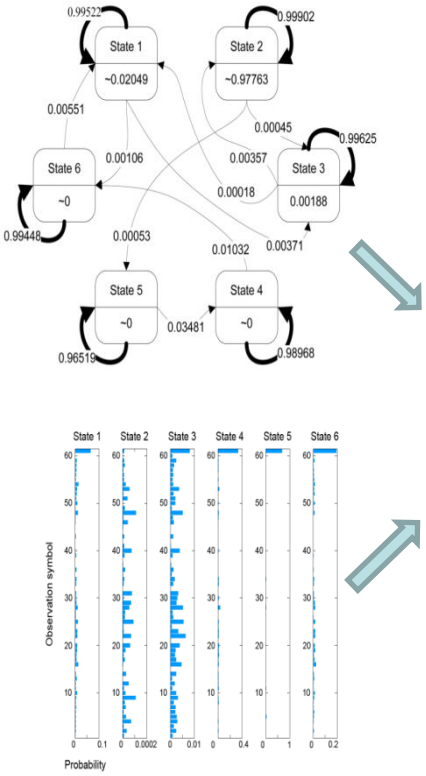
in vivo

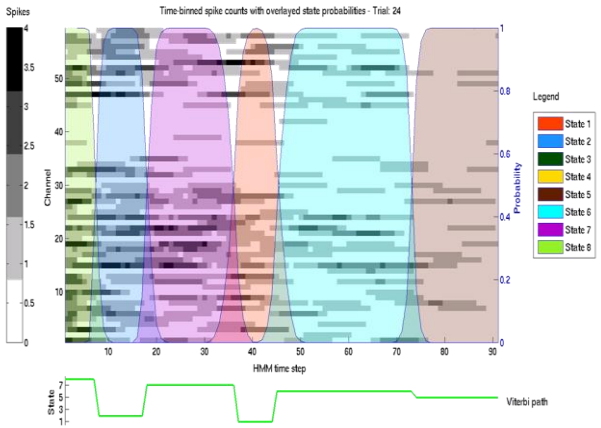


Jones et al., 2007

- Gustatory (taste) stimulus responses in rats (Jones et al,2007)
- Delayed localization task (Seidemann et al., '96)
- Stages of movement planning in monkeys, (Kemere et al., '08)

in animat





Network topology development

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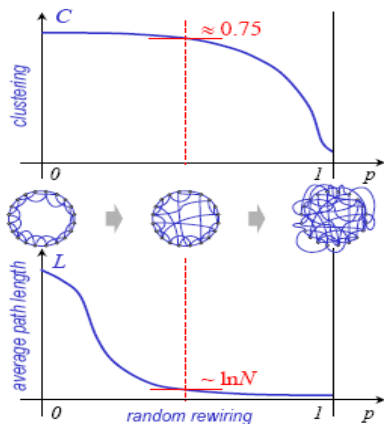
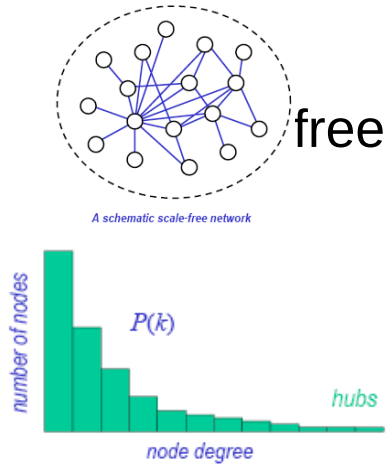
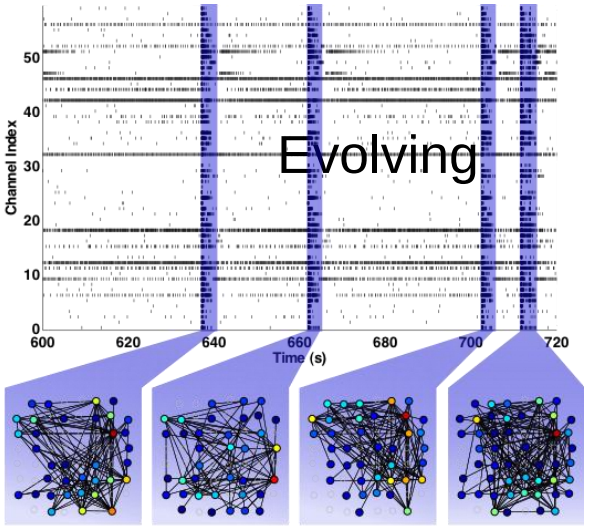


free

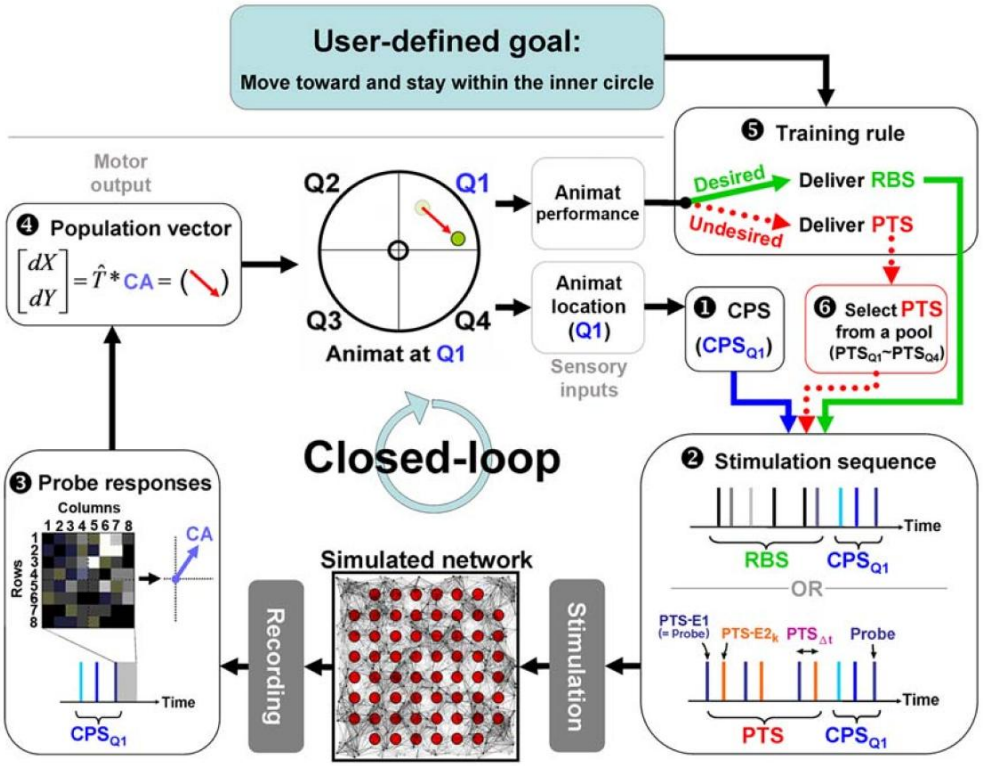


Evolving

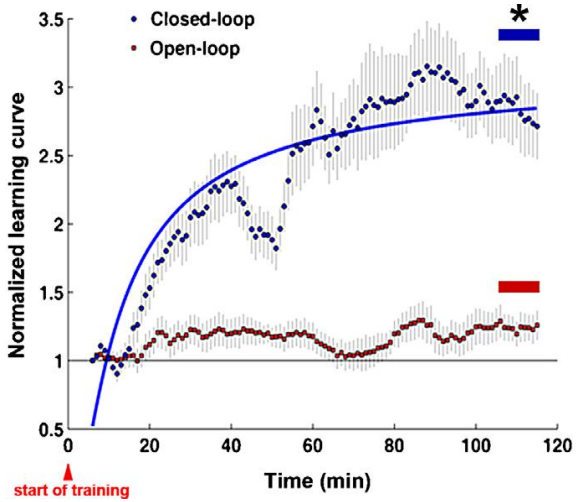


- **Immature cultures: a random topology**
- **Small-world network properties develop**: increased clustering, low mean path length
- Node degree distribution shows an increase in nodes with high degree as the cultures age – highly influential nodes (**hubs**)
- Link persistence increases – highly influential links

Goal Learning



Chao et al, (08)



Could animats be an answer and escape from CRA?

- Cultures develop functional properties analogous to *reported in vivo*
- indicative of systematic biological mechanisms shaping the information flow and cognitive function in vivo
- Subject to conditioning
  - Learning (Hebbian ?)
- Robot with biological brain = CRA reply in overdrive?
  - Embodiment or envatment? (Cosmelli, Thompson, 2011)
  - envatment not sufficient
  - Animat - still encased in lifeless robotic shell

Conclusions:

- Modern cognitive robotics does not escape CRA
  - Adding new sensors/actuators does not do justice to true embodiment
- But neither do animats or Manchurian rodents (not yet)
- We need to take intentional states seriously
  - Ways forward?
    - Full enactivism and neurophenomenology (Varela, Thompson)
    - Damasio's somatic markers
    - Metabolic drives and neuroenergetics
    - Bickhard's thermodynamics of living systems

"The best material model of a cat is another, or preferably the same, cat"

N. Wiener, A. Rosenblueth, *Philosophy of Science*, 1945

Thank you!