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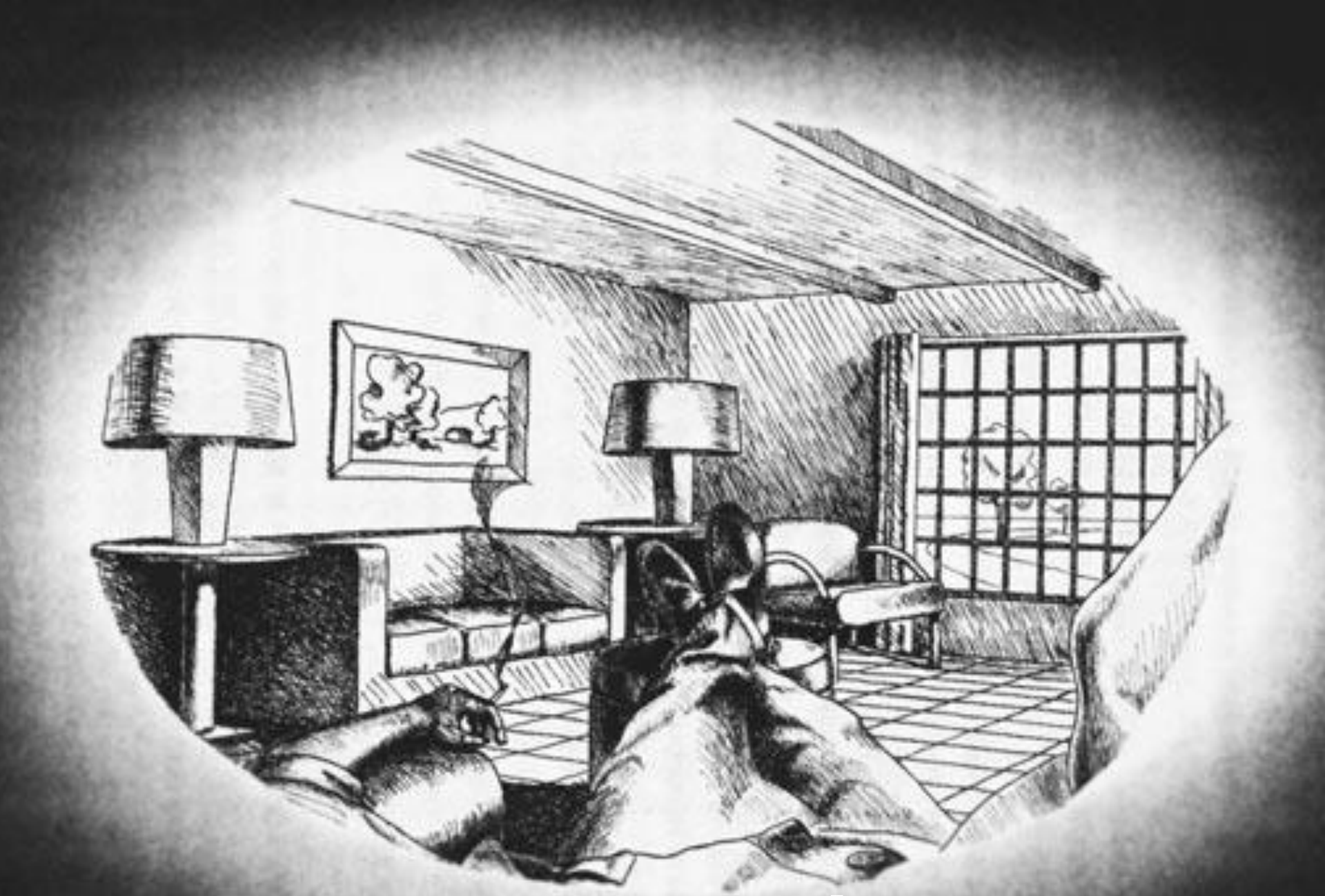
A Blob of View
Early nervous systems and the animal sensorimotor organization

› Fred Keijzer / Department of Theoretical Philosophy/ Universit of Groningen

Earth-based view on the universe



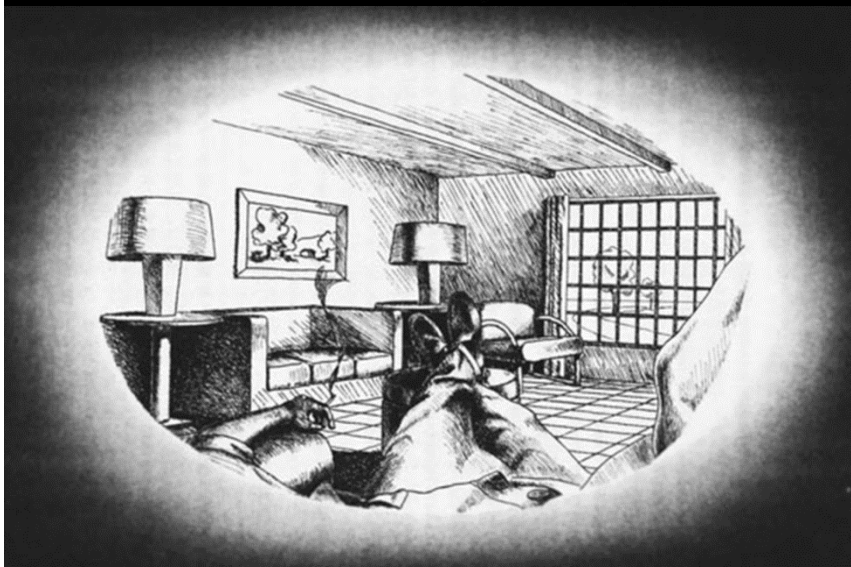
First-person view on the universe

Overview

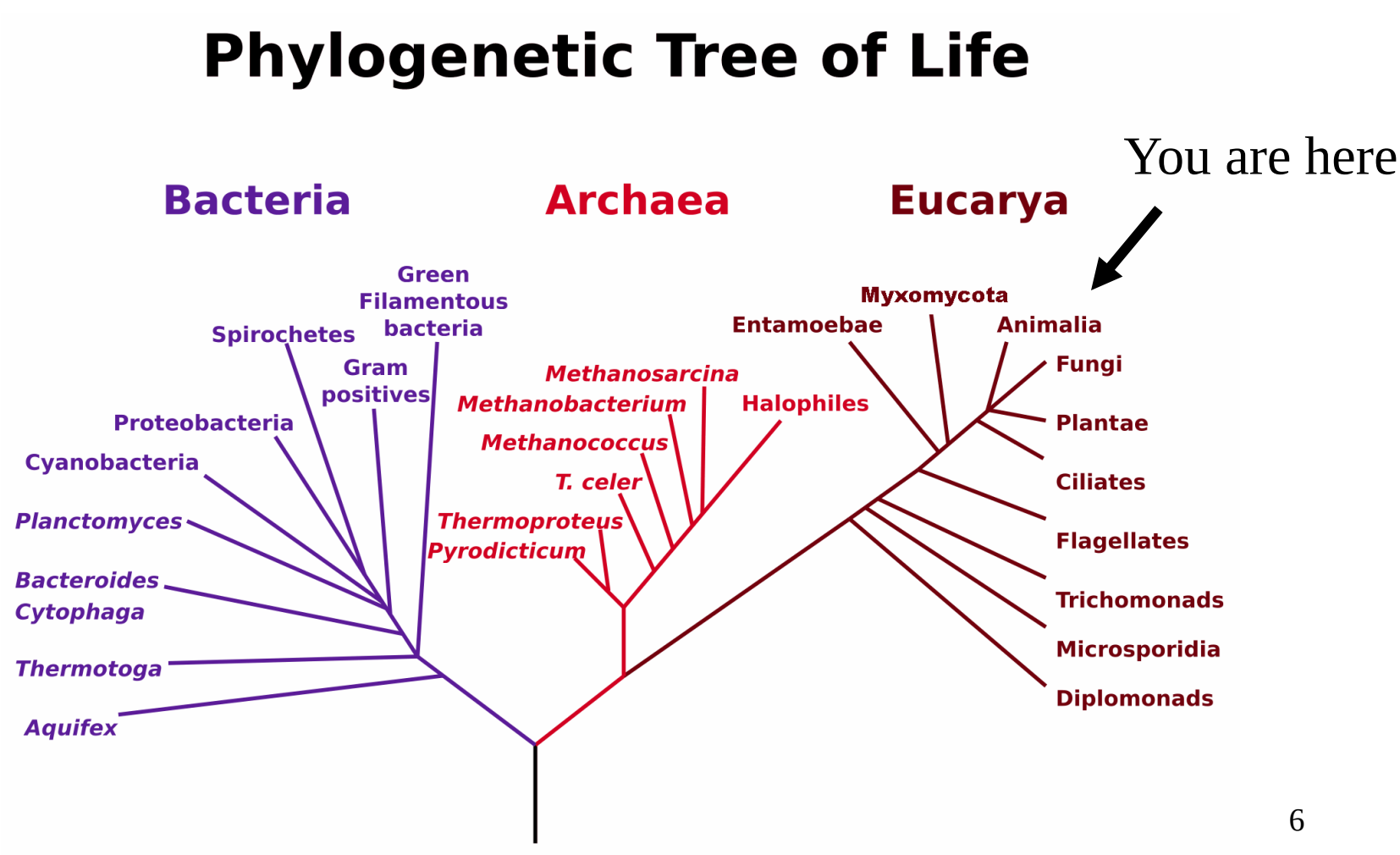
- How did an animal point of view originate?
- From a unicellular to a multicellular organization
- The origins of nervous systems
- Blobs of view
- Blobs with centralized control
- Conceptual implications of this blob-brain proposal

How did an animal point of view originate?

- Having a point of view
  - Differentiating self and world
- What do brains do?
  - Implementing mind?
  - Or?
- Focus on the evolutionary origins of the animal nervous system



From a unicellular to a multicellular organization



The animal body and nervous system

- A multicellular organization
- A major evolutionary transition
- Animals can be:
  - Large (centimeter/meter range);
  - Capable of sensing and acting on that scale;
  - Fast (acting in seconds to milliseconds).
- The evolution of MC motility and sensing is a key issue

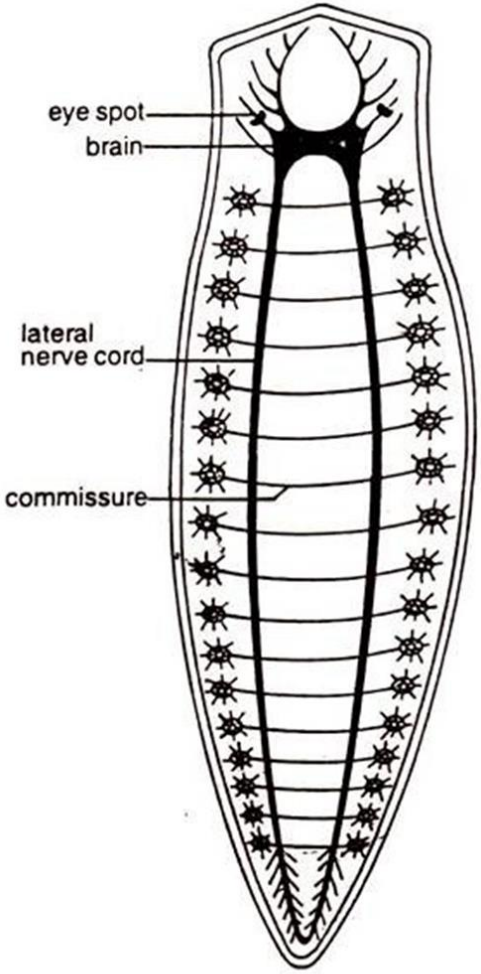
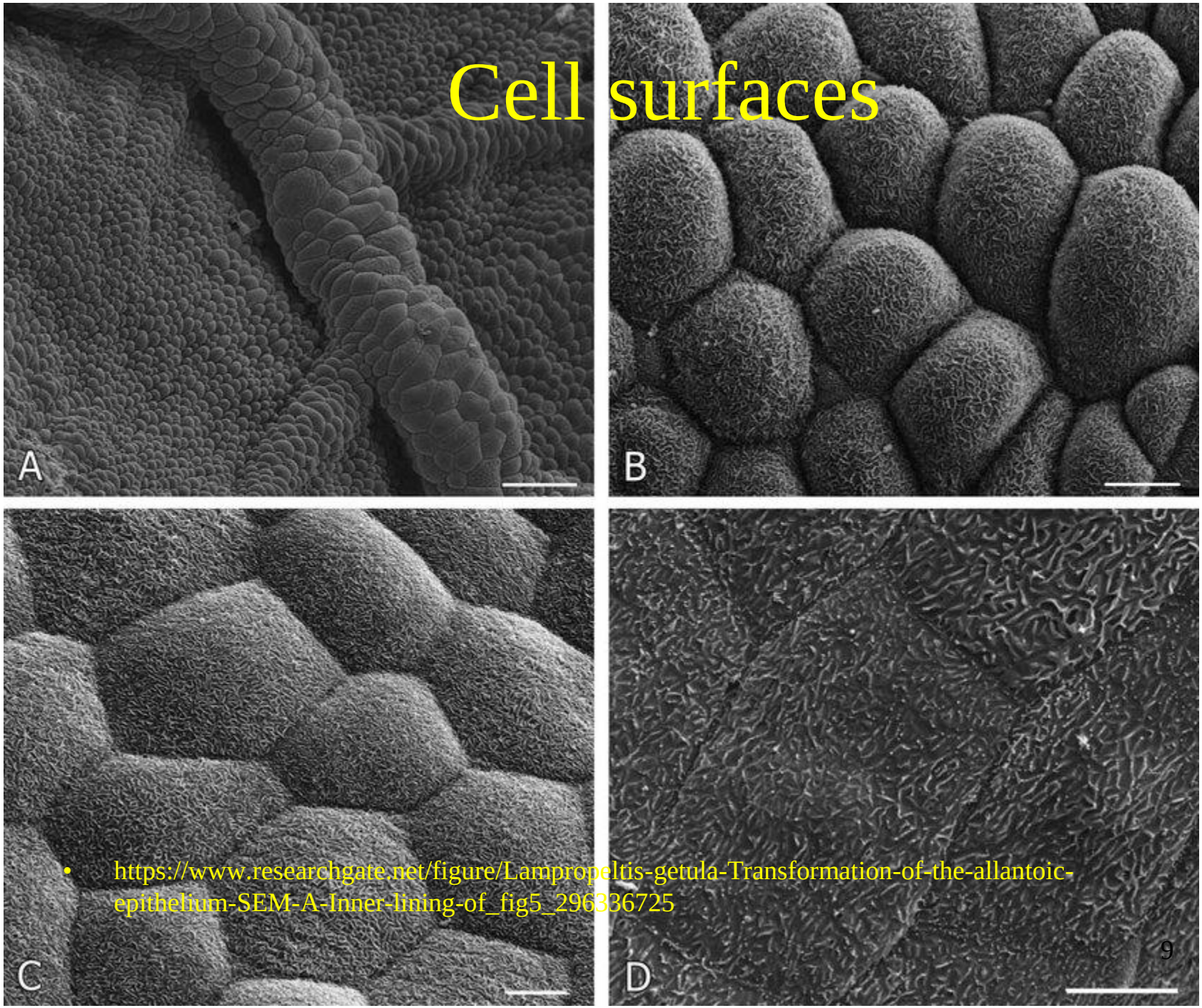


Fig. 13.2. Planaria sp. Nervous system

Example:
A multicellular (MC) sensory problem

- Without ascription:
- How can complex biochemical processes, happening at a macromolecular and cellular level, become sensitive to ‘the’ macroscopic structures of the world (for example surface structures, rocks, trees or tables?

Cell surfaces



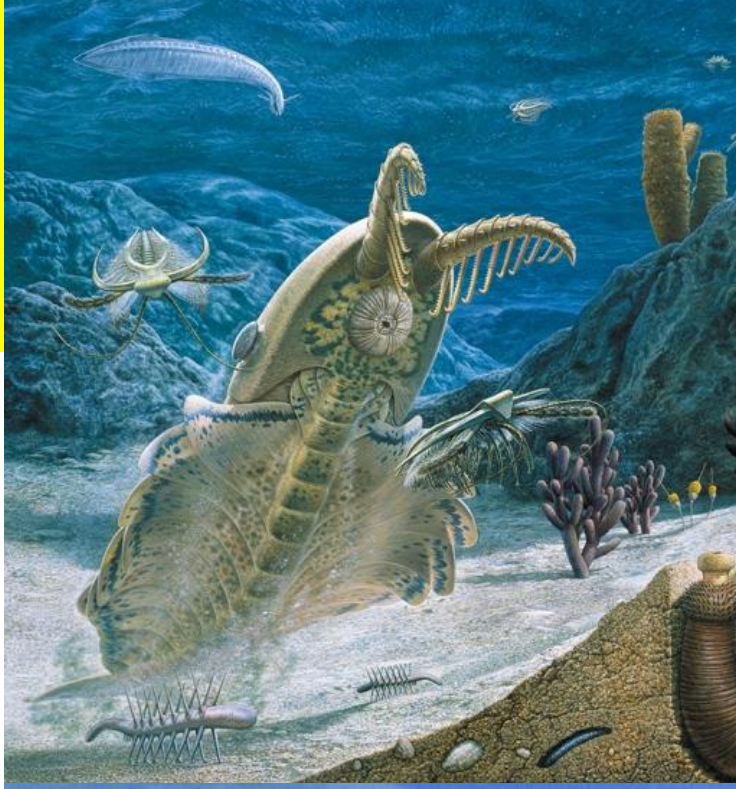
- https://www.researchgate.net/figure/Lampropeltis-getula-Transformation-of-the-allantoic-epithelium-SEM-A-Inner-lining-of_fig5_296336725

Animal senses

- Can assess much larger structures, including surface texture, objects and spatial lay-out
- Sensory modalities:
  - Touch
  - Vision
  - Hearing
  - Smell
  - Taste

The origins of nervous systems

- The Cambrian Explosion (542 Million years ago)
- The first nervous systems must have evolved earlier
- How did this come to pass?



Developing an option space for early nervous systems

- Integrate behavior, physiology and development
- Input-output view (IO)
  - Complex information processing
- Internal coordination view (IC)
  - Coordinating muscles to enable motility

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Review

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Subject Areas:
behaviour, evolution, neuroscience, theoretical biology

Keywords:
nervous system evolution, peristalsis, phototaxis, cnidarian, ctenophore, sponge

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An option space for early neural evolution

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The origin of nervous systems has traditionally been discussed within two conceptual frameworks. Input–output models stress the sensory-motor aspects of nervous systems, while internal coordination models emphasize the role of nervous systems in coordinating multicellular activity, especially muscle-based motility. Here we consider both frameworks and apply them to describe aspects of each of three main groups of phenomena that nervous systems control: behaviour, physiology and development. We argue that both frameworks and all three aspects of nervous system function need to be considered for a comprehensive discussion of nervous system origins. This broad mapping of the option space enables an overview of the many influences and constraints that may have played a role in the evolution of the first nervous systems.

1. Introduction

The origin of the nervous system was an evolutionary event that fundamentally changed how control is achieved within a multicellular body. Recent progress in genomics, phylogenetics, developmental biology and the study of simple nervous systems has provided a wealth of new empirical information that bears on the earliest stages in neural evolution. However, many of the conceptual frameworks that are used to discuss this work recognize only a limited subset of the range of roles that nervous systems can play; the neural control of development and physiology is often sidelined or omitted in favour of an exclusive focus on behaviour. In addition, these frameworks tend to employ an overly simple conception of the role of neural activity in the adaptive shaping of behaviour itself. The aim of this paper is to organize ideas and hypotheses in this area in a global way by charting the 'option space' for hypotheses about early neural evolution, making explicit the entire range of functions that early nervous systems may have played.

Historically, the origin of nervous systems has been discussed in the light of two different conceptual models. We call these the *input–output* (IO) and *internal coordination* (IC) models. The two models emphasize two different aspects of the nervous system as a control device. According to IO models, the main role of the nervous system is to receive sensory information and process it to produce meaningful motor output. Braitenberg's 'vehicles' [1] represent a simple conceptual IO model of an organism, where directional light sensors modify the speed of wheels in a moving vehicle.

In contrast to IO models, IC models hold that a central role of early nervous systems was to induce and coordinate activity internal to large multicellular organizations. While an IO model tends to assume an operational effector system and addresses how this system is to be put to use, an IC model highlights the evolutionary shift involved in generating new multicellular effectors. In particular, the use of extensive contractile tissues (muscle) by large organisms is an important evolutionary invention. Achieving organized movement in a muscle is a demanding task that should not be taken for granted, as sometimes happens in discussions employing an IO framework.

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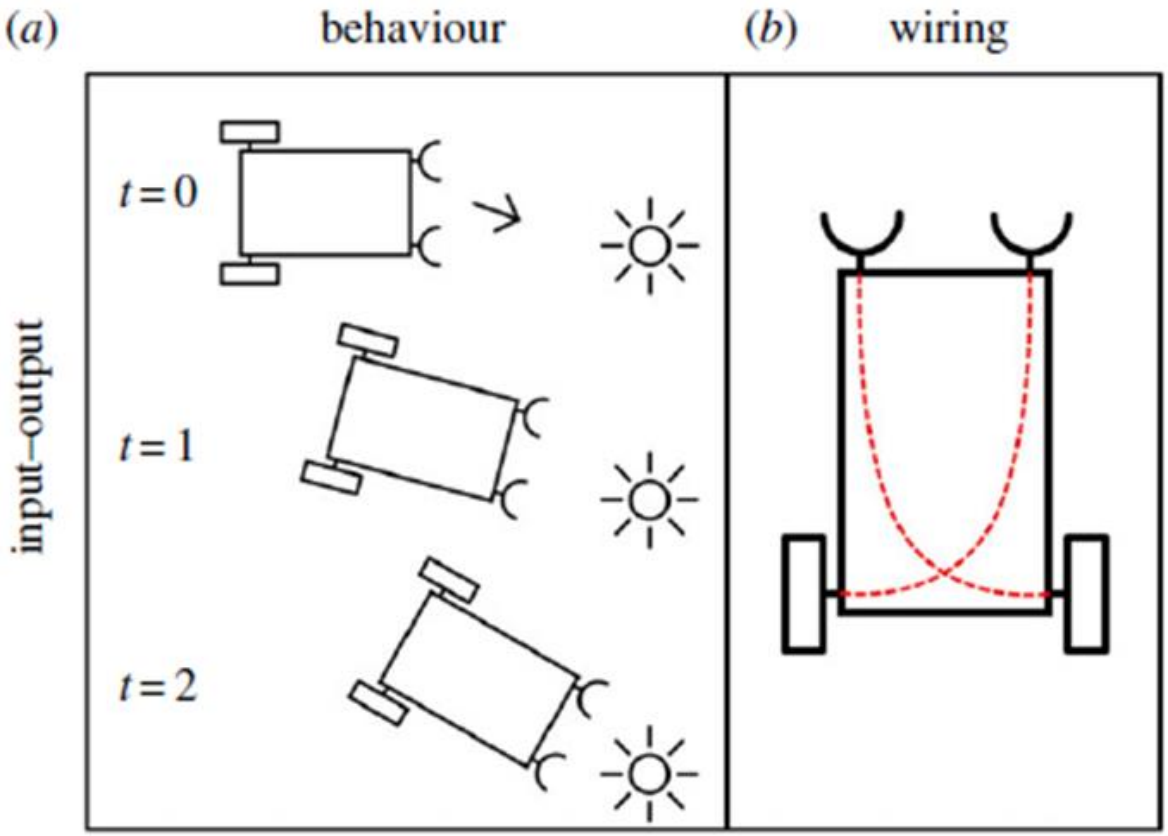
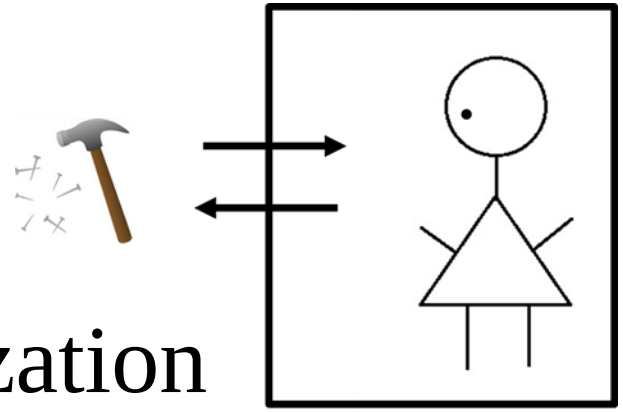
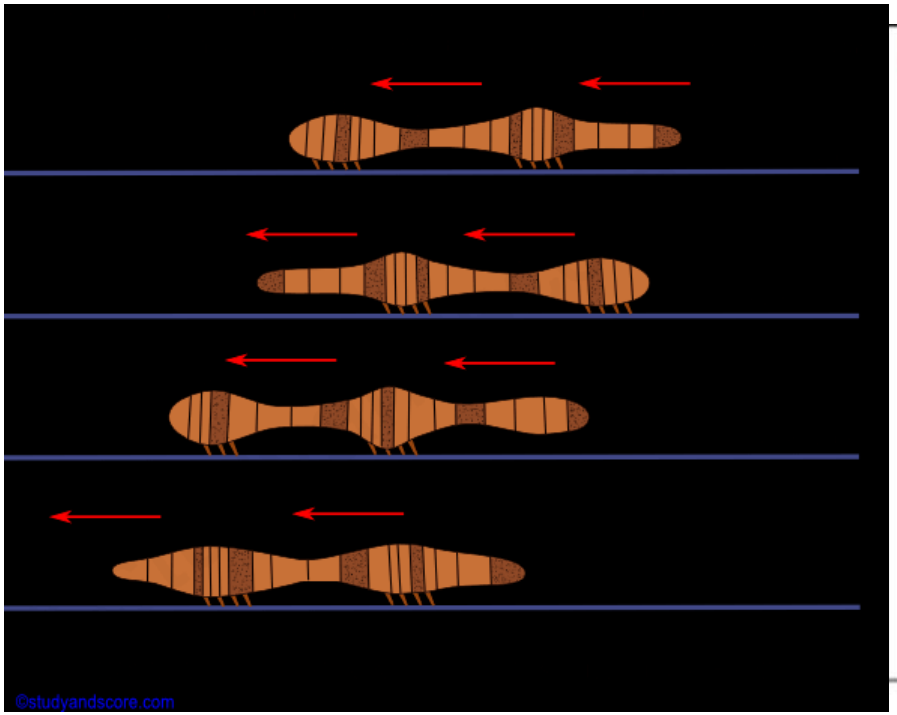
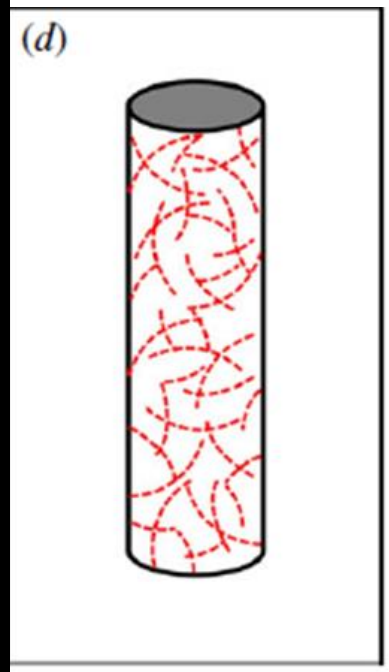




An Input-Output (IO) architecture for neural organization

An Internal Coordination (IC) view on neural organization

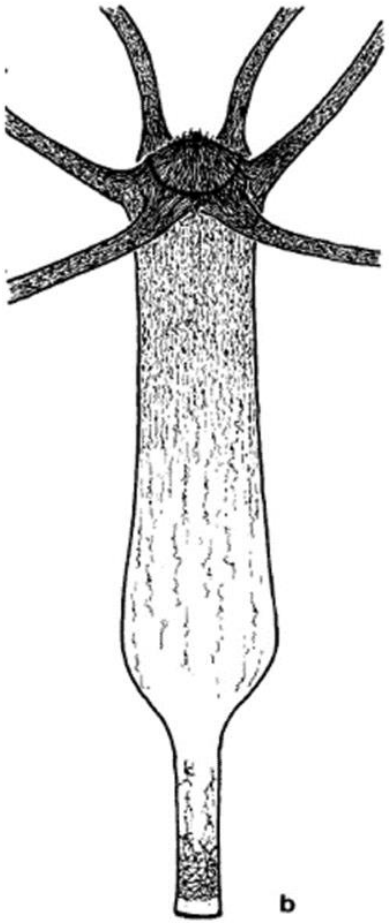




- Nervous systems (initially) evolved to organize coordinated muscle contraction

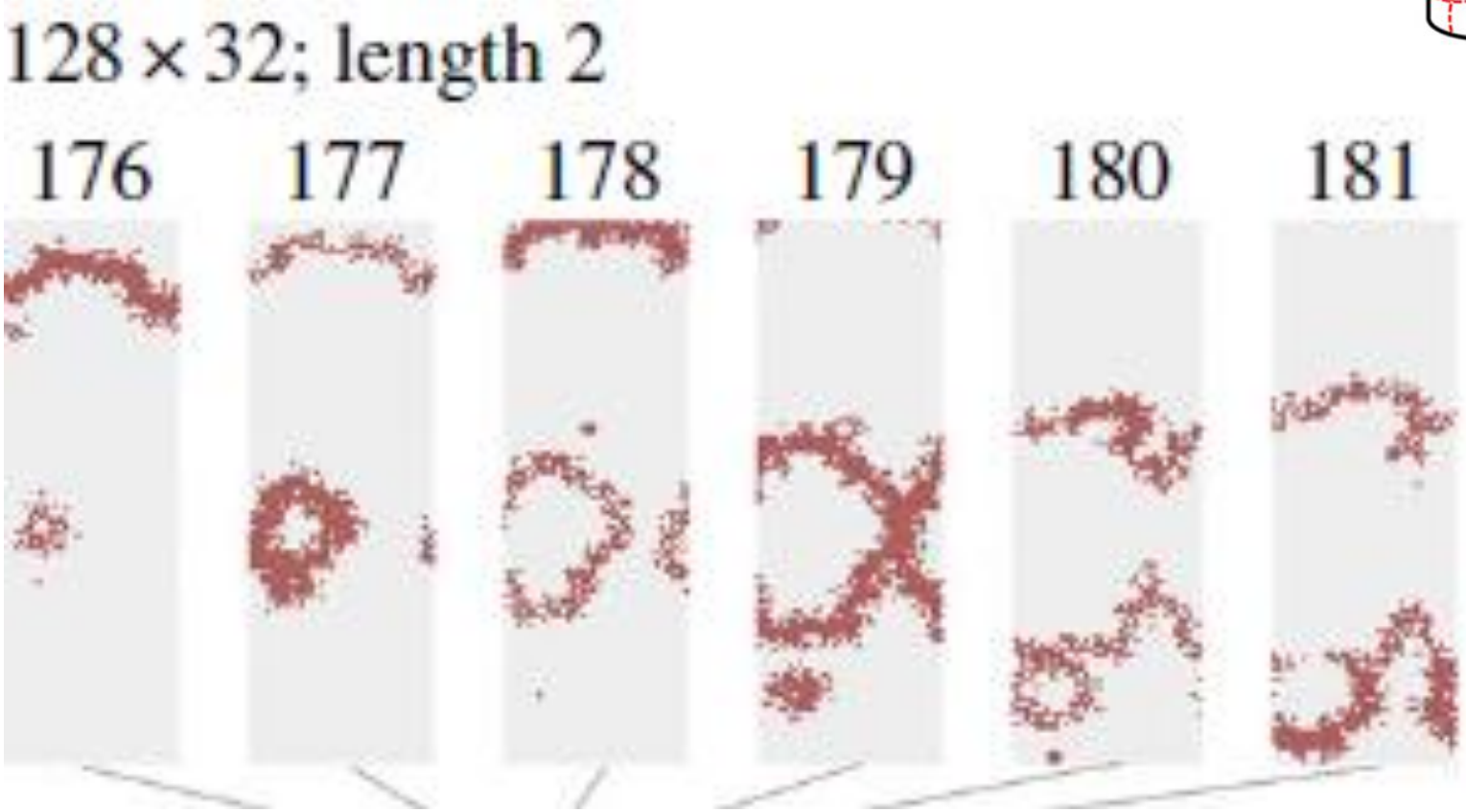
Skin Brain Thesis
(Keijzer et al., 2013)

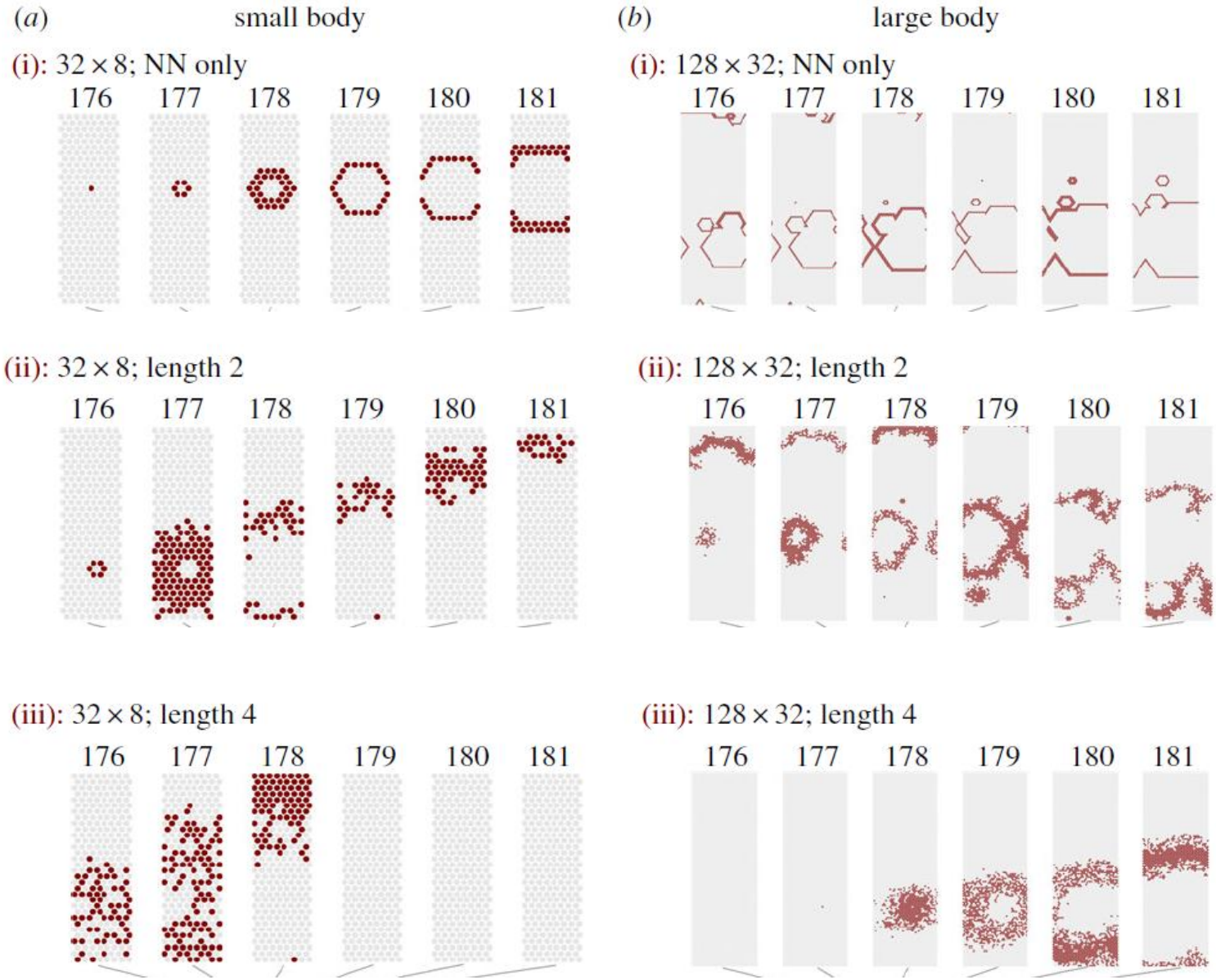
- Inspired by Carl Pantin (and George Mackie)
- Nerve nets evolved in close connection to the spatial lay-out of the contractile body
- A muscle/contractile (Pantin) surface



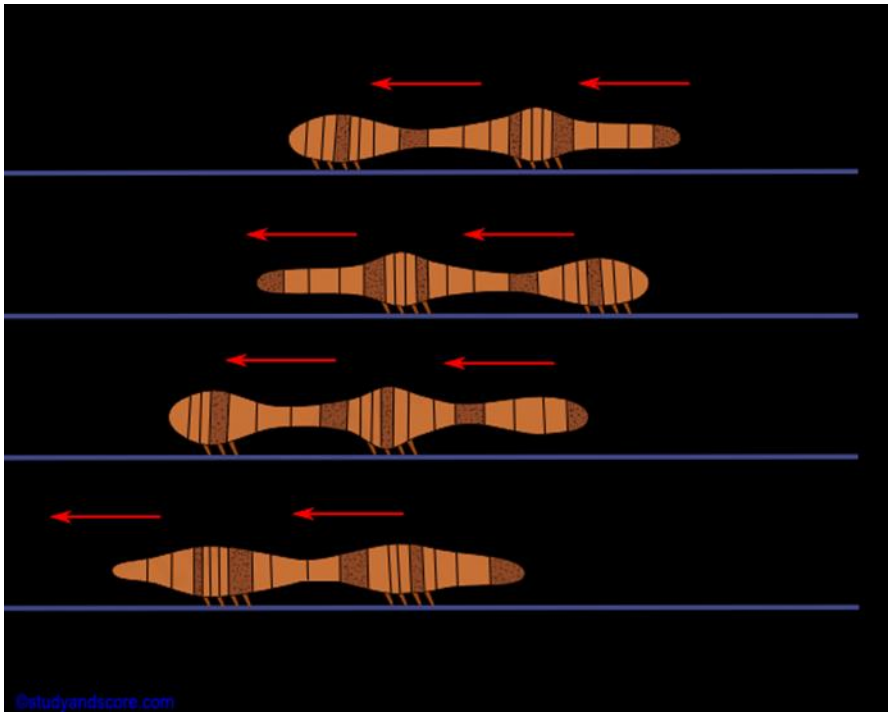
Simulation of acitivity patterns across an epithelial surface

(De Wiljes et al, 2017)





Short and random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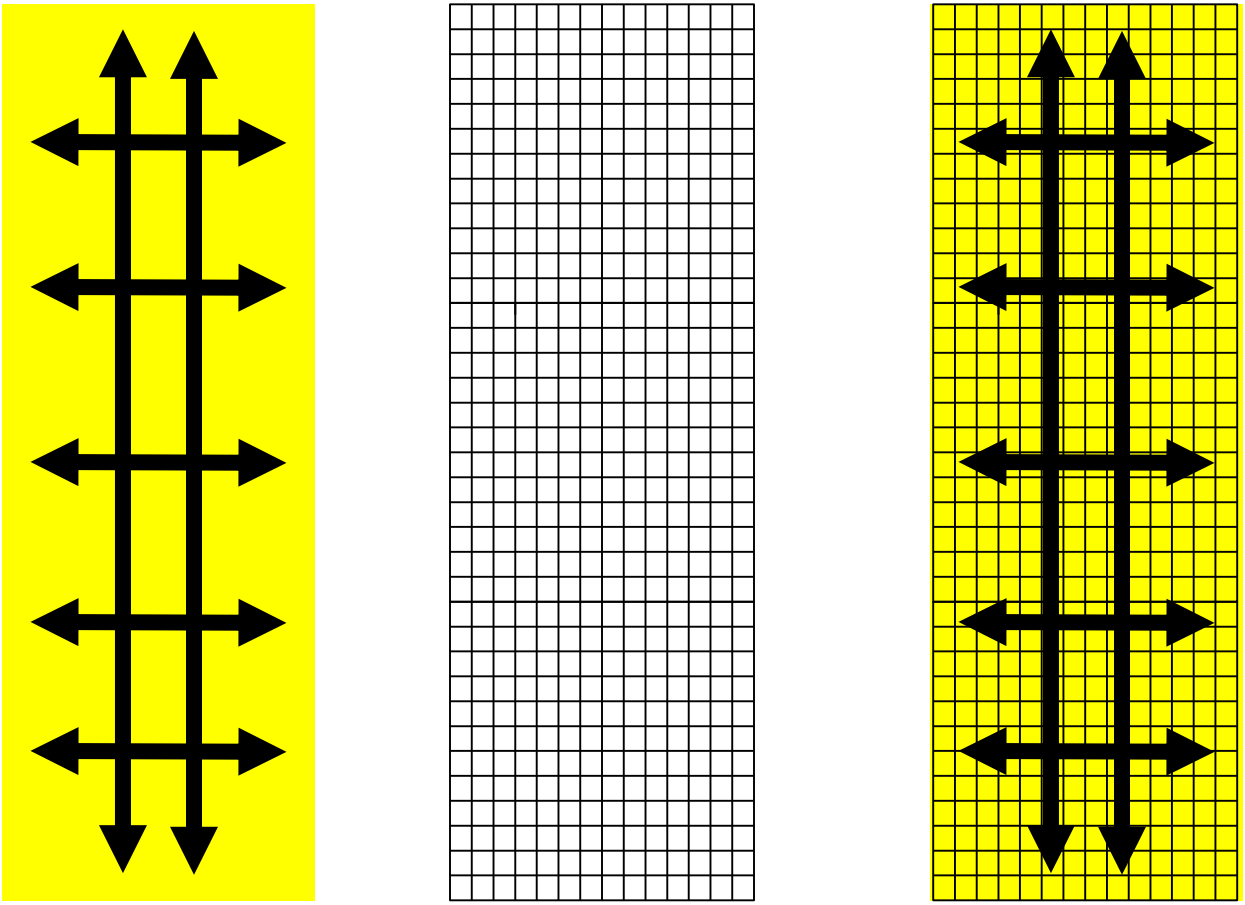
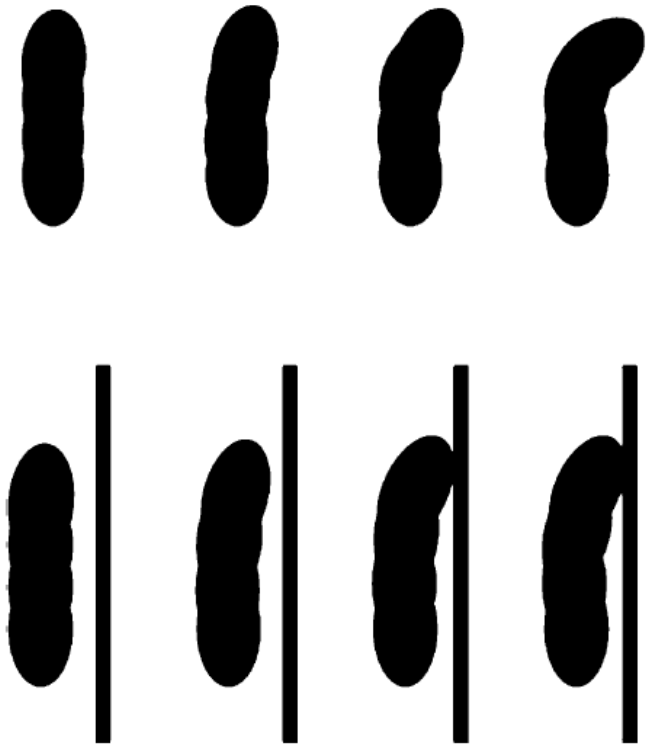
A Pantin surface and its nerve net



- Combining physical stress and tension signaling with electrical signaling

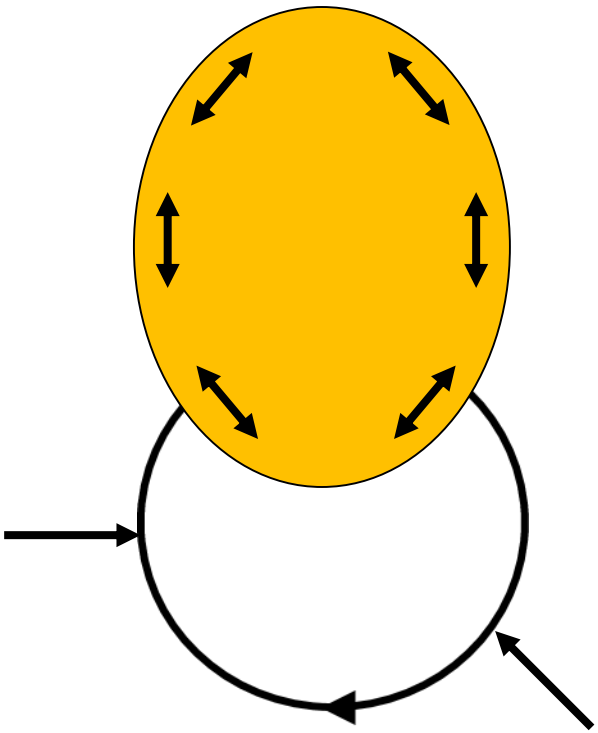
A blob of view

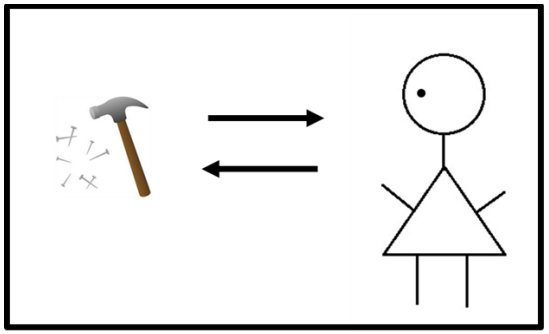


- From motility to self-initiated active sensing
- Patterning a contractile surface requires forms of internal feedback to adapt and stabilize
- But internal feedback implies sensitivity to external events

The animal sensorimotor organization (ASMO)

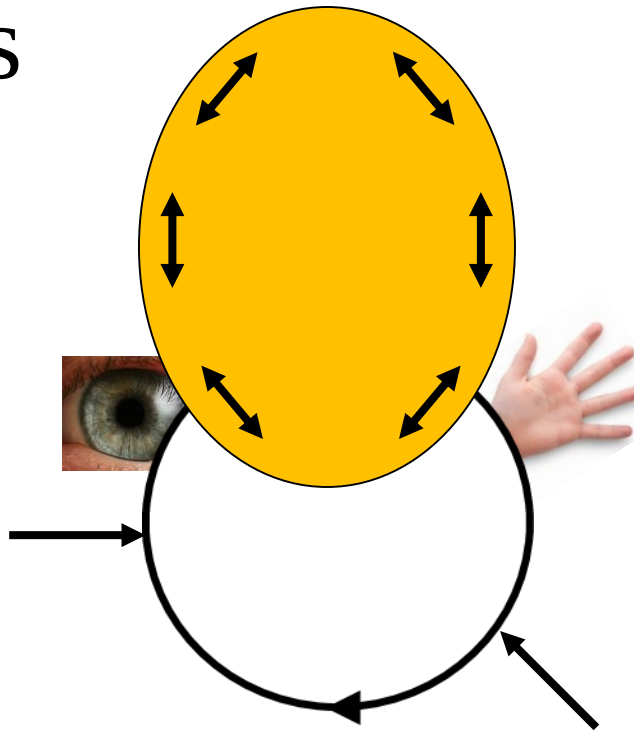
- A moving and sensing animal body sets itself apart from an environment and in doing so creates an organization that senses this external world
- Proprioceptive perception of stress and tension forces that act on the body is basic





Adding sensory modalities

- Only ‘muscle sense’ constitutes an ideal case
- The ASMO will also become sensitive to external signals that vary on the basis of self-induced motility
- Additional modalities
  - Tactile; Light; Sound; Chemical; Electricity

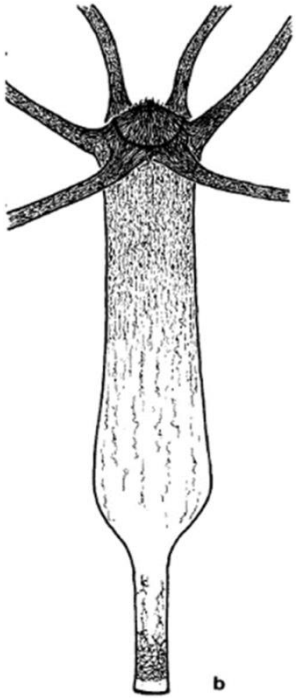


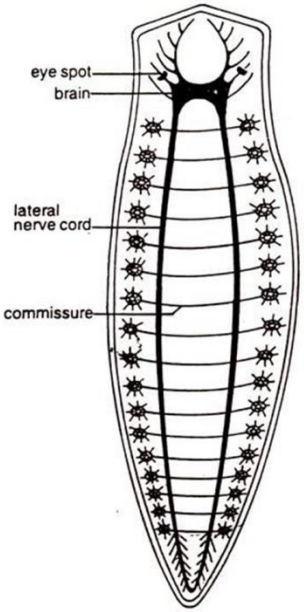
Affordances

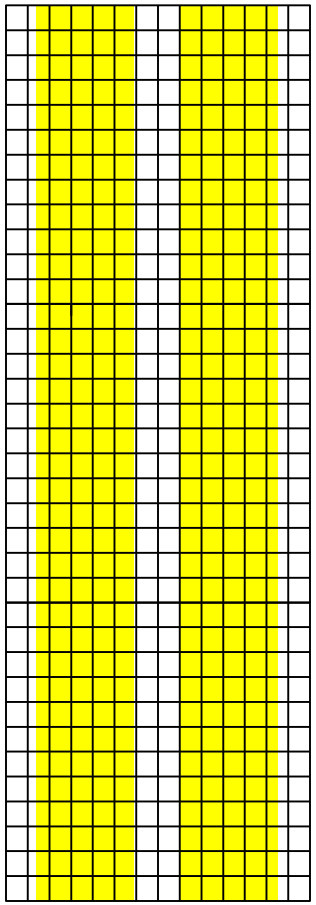
Blobs with centralized control

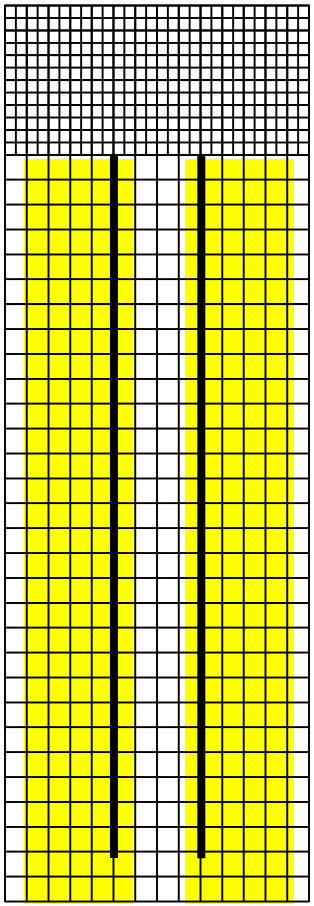
- To add additional sensory modalities;
- and increase the differentiation of the muscle (Pantin) surface;
- a more centralized/cephalized nervous system seems to be required
- Is this compatible with the blob of view sketched above?

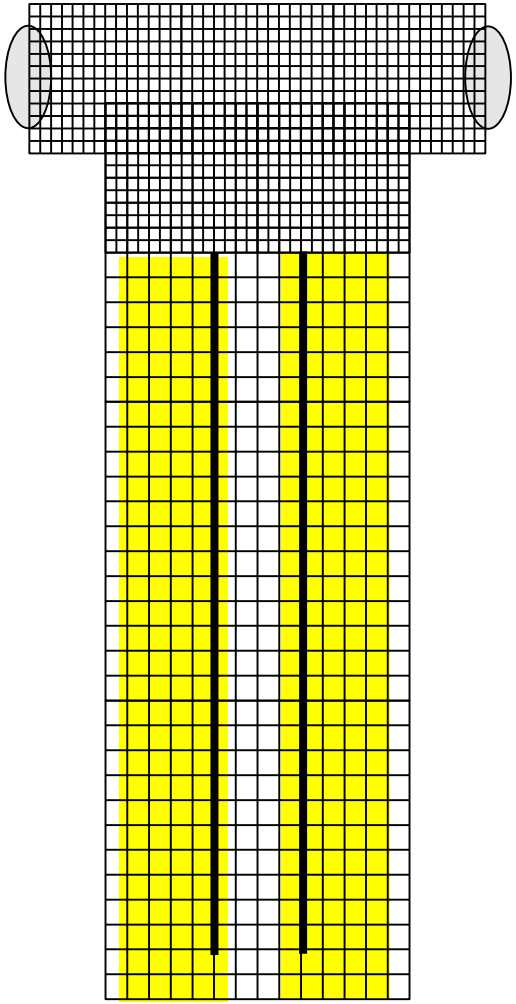
Centralizing nervous systems



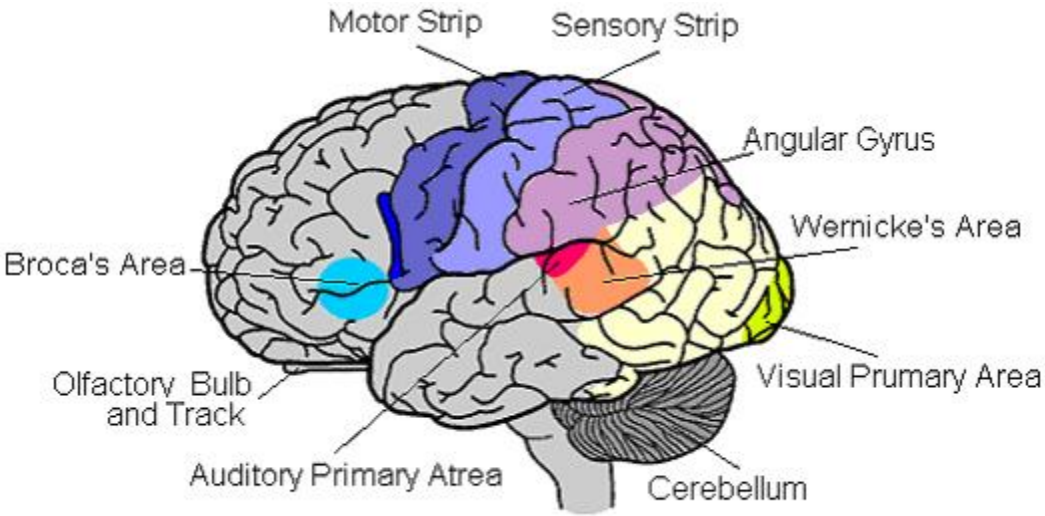








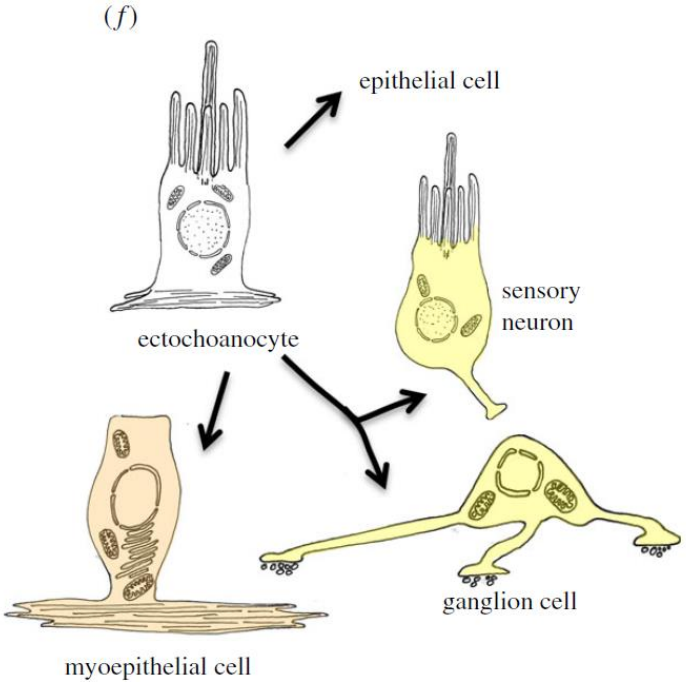
A Central Blob Brain?

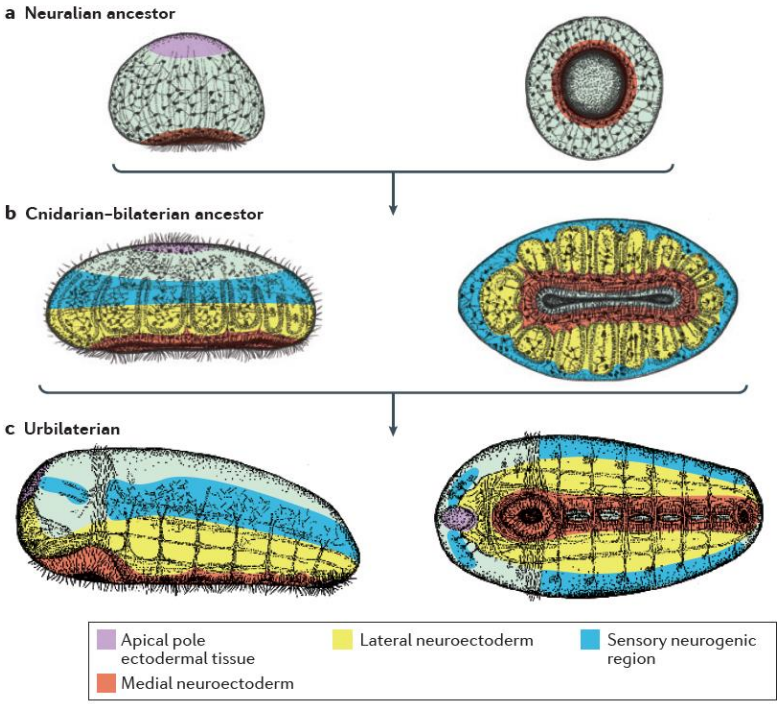


- The proposal:
- Neural ganglia are essentially spatially organized nerve nets but in an extended and condensed form
- Brains are condensed nerve nets instead of a sequential input-output architecture

Empirical context: Evolution of early nervous systems

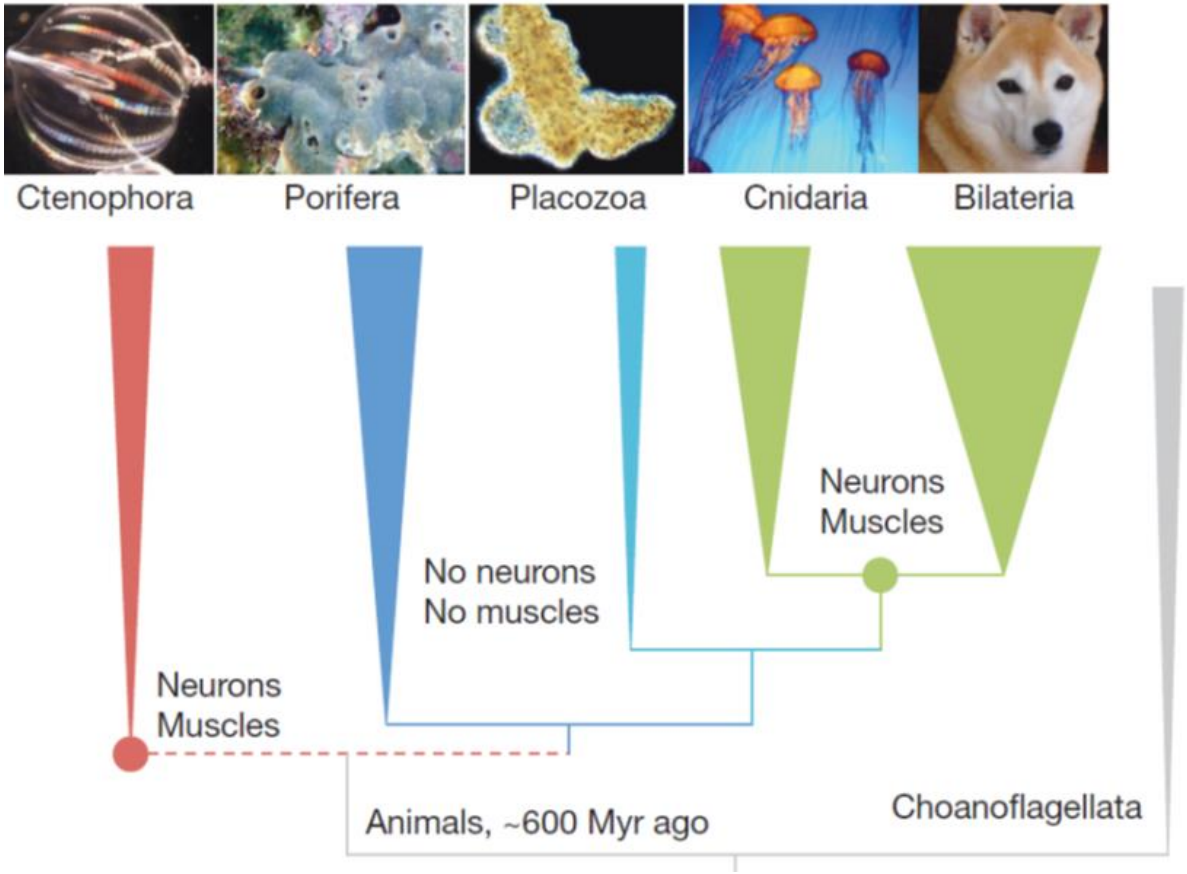
- Detlev Arendt's Lab
  - Gradual cell differentiation
  - Universal connection muscle and neural cells
  - A 'chimeric brain'





Moroz (2009; et al., 2014)

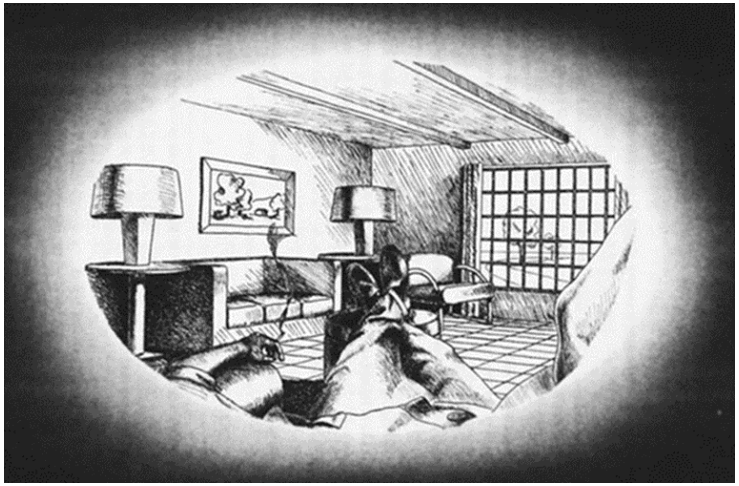
- Nervous systems may have evolved twice (or even more)



Conceptual implications of this blob-brain proposal

- A conceptual alternative for an IO architecture
- Active touch (including proprioception) is fundamental for sensing
- Brains can be reinterpreted as an extended and condensed nerve net acting as a modulator of contraction-based activity (and other fucntions)
- A blob-brain is conceptually natural in contrast to a ‘mind-brain’
- Can be incrementally extended and refined in many different ways during evolution

Thanks for your attention!



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