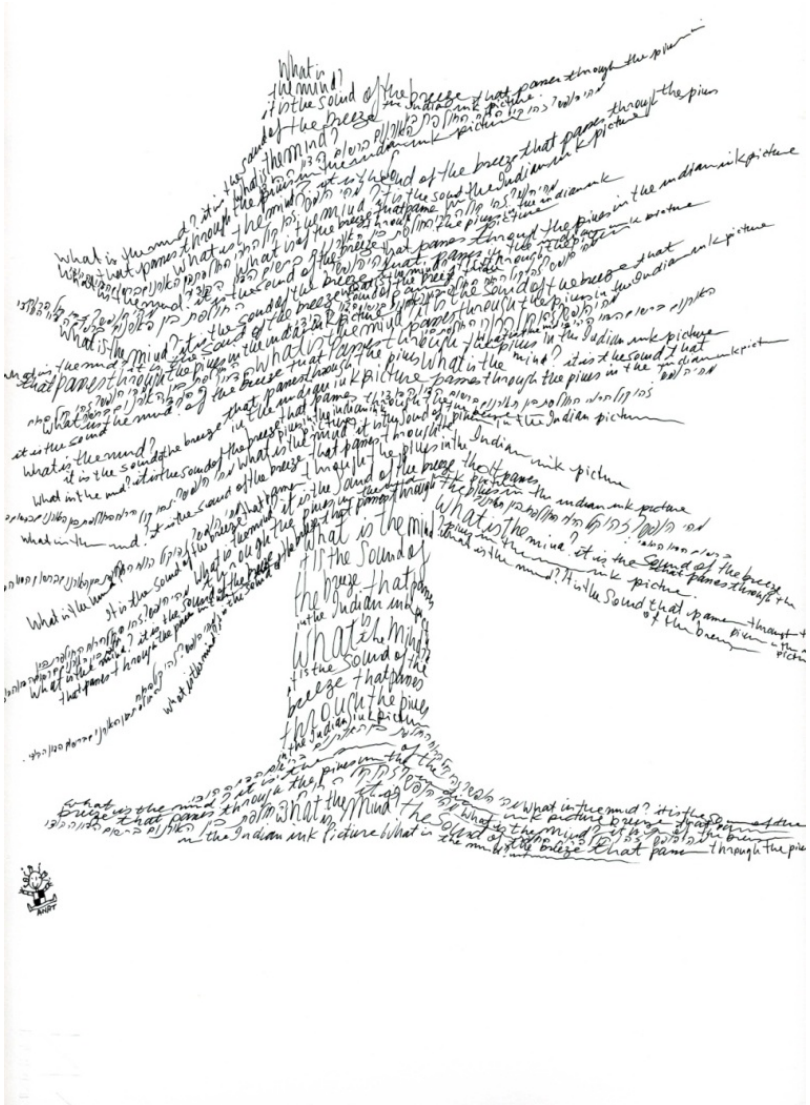
Consciousness: An Evolutionary-Transition Approach

Mexico, September 2014

Eva Jablonka and Simona Ginsburg



Many thanks to:

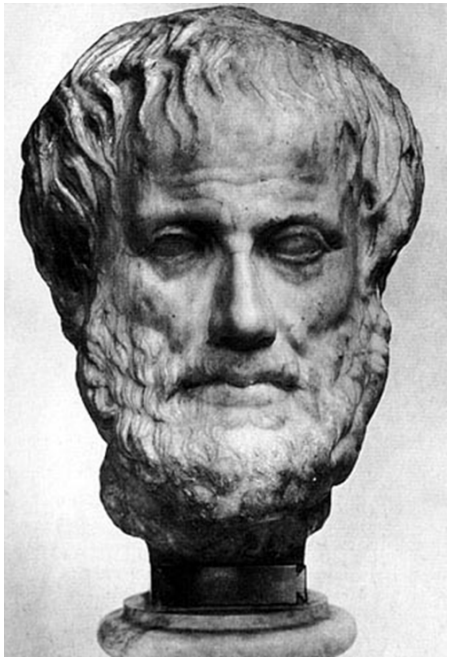
Marion Lamb

Anna Zeligowski

Students and colleagues

The Organizers

Aristotle's teleological carving



Aristotle "soul" (*psyche*) is a principle of living organization. It has three hierarchically-ordered incarnations:

The reproductive or nutritive soul – the most basic type of living organization which is characterized by self-maintenance and self reproduction.
telos: survival and reproduction)

The sensitive soul - built on the previous and characterized by sensation, movement, desire and motivation (teloi: felt needs and passions, hunger, pain, joy, sadness, etc.)

The rational soul – built on the previous two, characterized by rational thinking and striving for ideals (teloi: the good, the beautiful, etc.)

Experiencing (consciousness) is the teleological, dynamic set of organizational processes found in organisms having a sensitive soul

This translates to the following evolutionary questions:

The evolutionary origin of the nutritive soul = the evolutionary origin of life

The evolutionary origin of the sensitive soul = the evolutionary origin of experiencing

The evolutionary origin of rational soul = the evolutionary origin of symbolic representation

At some points during the history of the planet these major teleological transitions occurred; the transition-inspired approach has advantages:

- The type of organism that appeared immediately after the transition would be the simplest of its kind; derived dissociations and integrations that occurred at later evolutionary stages will not mask the fundamental properties of the process of experiencing; if we are able to identify the transition, it will enable us to recognize the most fundamental organizational principles that constitute experiencing.
- The evolutionary-transition framework can point to useful analogous explanatory strategies
- This perspective can change the framing of philosophical questions about the trait (life, consciousness, rationality)

Problem: **how do we identify the simplest system if it is very different from those we are familiar with?**

How we go about it:

Lists of necessary and sufficient characteristics and conditions (criteria)

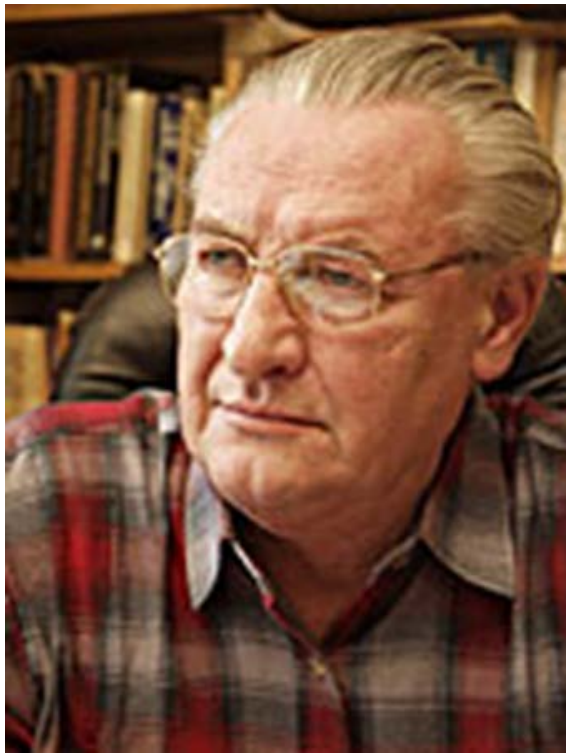
Models spelling out the **dynamic organization** that can instantiate them

A transition marker

Evolutionary scenarios: when, where, and how did the process happen?

The emergence of a **new telos**

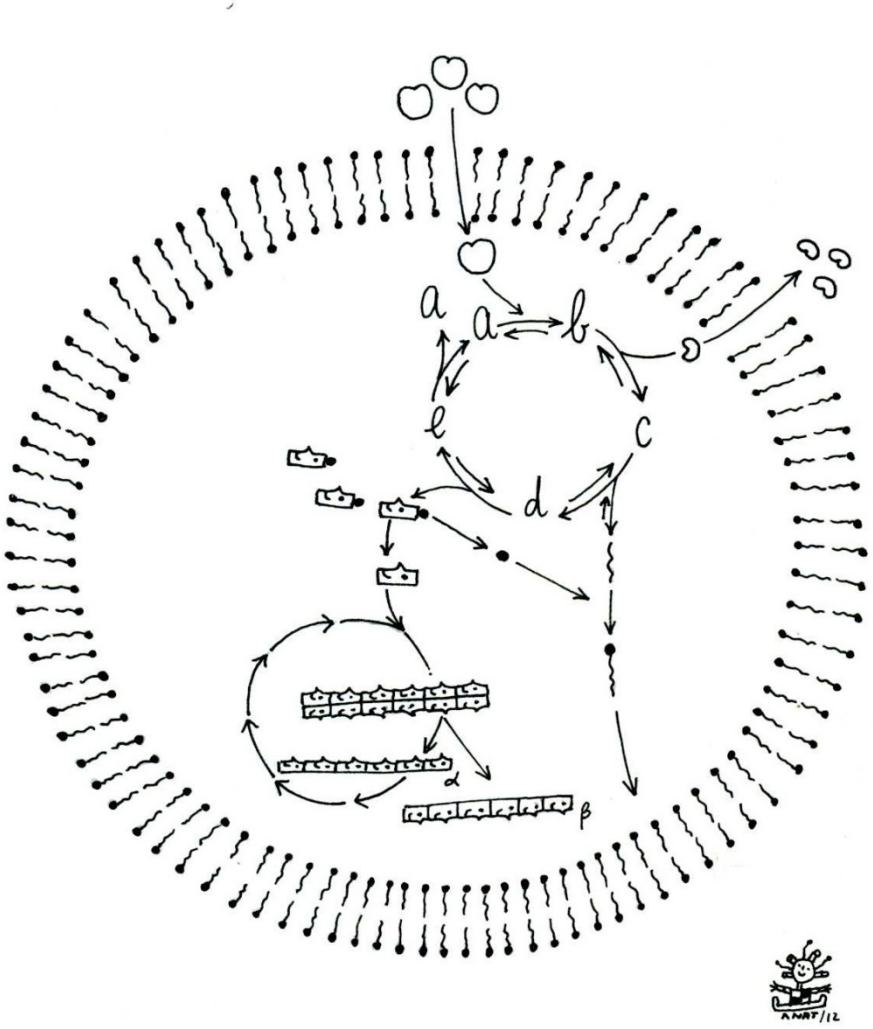
A conceptually clear example of a minimal life system with stability based on chemical dynamics or three coupled autocatalytic systems is the chemoton, invented by Tibor Gánti.

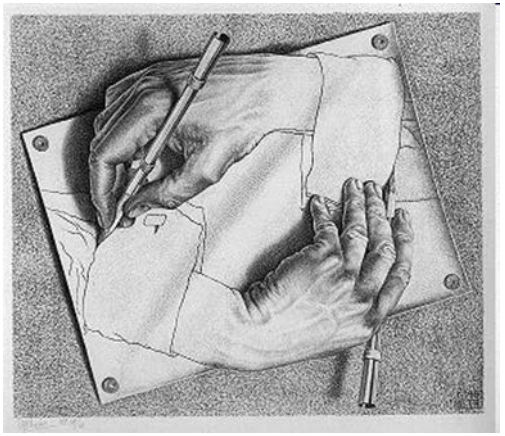


I. Gánti's List

1. Inherent unity
2. Metabolism
3. Inherent stability
4. Information-carrying sub-system
5. Program control
6. Growth and multiplication
7. Hereditary system enabling open-ended evolution
8. Mortality

II. Dynamics





III. The Transition Marker: unlimited heredity

In *The Major Transitions in Evolution* (1995), John Maynard Smith and Eors Szathmary discussed the transition from chemistry to biology. They recognized the futility of seeking a sufficient set of criteria of life, yet thought that some criteria—having heredity and being able to evolve by natural selection—are crucial because *they have led, and must almost inevitably lead to life*. Following Ganti, they suggested a distinction between **limited and unlimited heredity**.

Limited heredity: the number of possible hereditary variants in the system is small, and therefore evolutionary change is extremely limited. Although systems with limited heredity are not fully living, they belong to the gray area between the nonliving and the living phases, and are on the evolutionary route to life if they evolve into systems with unlimited heredity.

Unlimited heredity: the number of hereditary variations is practically unlimited and evolution is therefore open-ended.

Unlimited heredity presupposes an autopoietic system

VI. Scenarios: experiments and chemical models

Oparin: simple organic monomers form spontaneously in reducing conditions on the ancient earth, in warm ponds. These monomers assemble spontaneously, grow by accretion and inevitably fragment ("reproduce"). Variation is inevitable, evolution by chemical-selection can occur.

Haldane: same conditions; self-replicating virus-like elements, which formed spontaneously in the warm soup. These viral-like systems evolved through chemical-natural selection to more complex entities, leading eventually to a cell-like organism.

Many more models…. For example:
Wächterhäuser: conditions are volcanic vents in the deep sea, in condition of high pressure and high temperature (100°C). Pressurized hot water with dissolved volcanic gases flows over catalytic metal solid surfaces like iron sulfide, carbon is fixed and organic compounds are formed and bind to the catalytic surface. The carbon fixation metabolism becomes autocatalytic by forming a metabolic cycle in the form of a primitive sulfur-dependent version of the reductive citric-acid cycle.

V. A new telos and the emergence of functional information

Functional information: a difference that makes a difference to the goal-directed (e.g. self-sustaining) behavior of a system.

Functional information emerged and evolved: it was an emergent property of some proto-living complex self-stabilizing systems, and it blossomed into necessary and exuberant existence with the origin of life.

It was function and goal-directedness which seemed to pre-20th century biologists and philosophers (e.g. Kant) irreducible to chemistry and physics, and hence requiring a new force or a new explanatory principle (for the 18th-20th century vitalists – a living-special force, élan vital, or a “primitive”)

What can we learn from the transition to life?

An evolutionary, transition-oriented approach may be promising

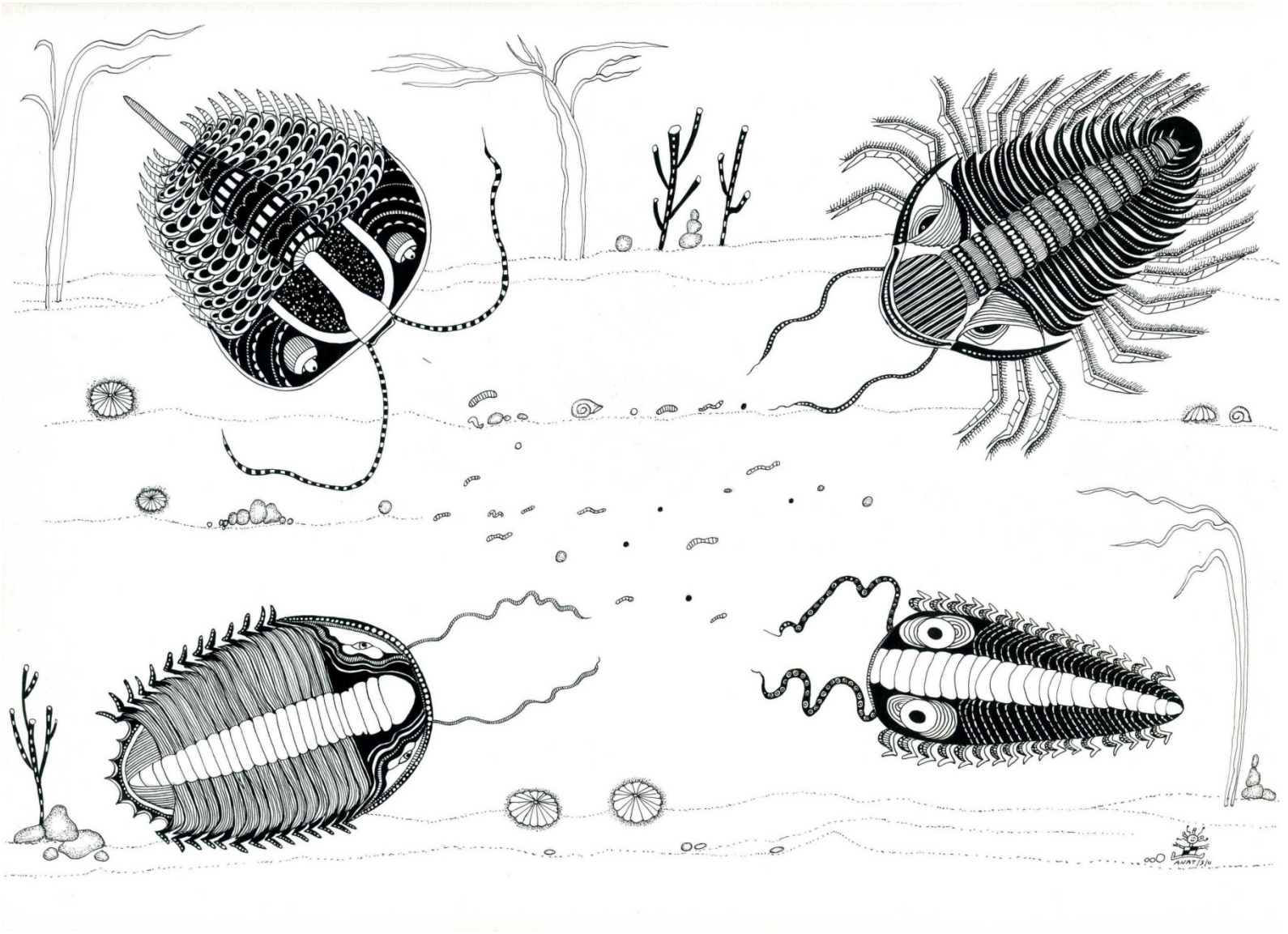
Continuity: what we have learned about the transition to life may be useful

We have to know what we are looking for - **crucial characteristics** of experiencing; which animal taxa exhibit consciousness;

Look for the kind of **dynamic organizational processes** that yield them and identify the **gray areas**

Look for an equivalent to a limited/unlimited heredity criterion to define the **transition marker**

The Transition to Experiencing



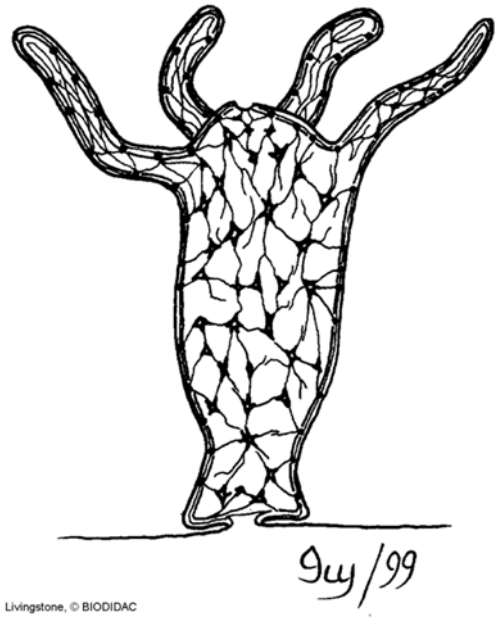
Mind can be understood only by showing how mind is evolved (Herbert Spencer 1855)

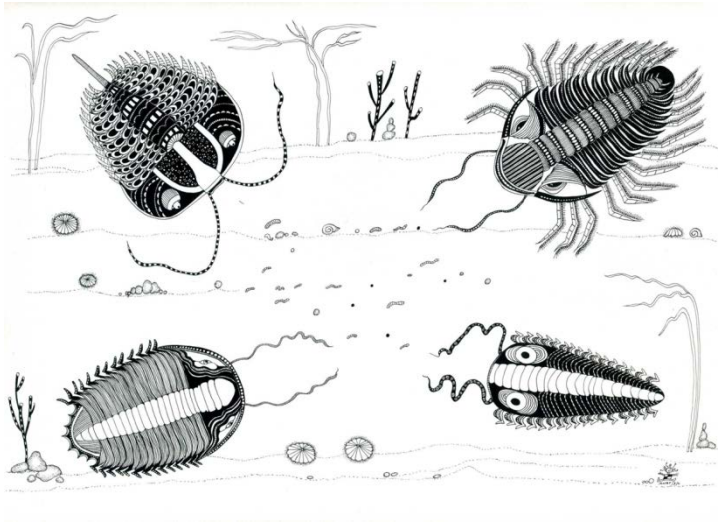
There were three major transitions involving :

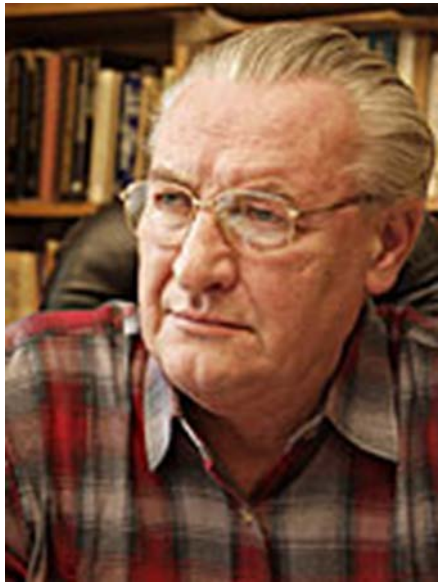
The transition to neural organization in metazoans

The transition to experiencing/consciousness

The transition to symbolic language







Point to important/crucial necessary characteristics/conditions (list)

Suggest instantiating dynamics

Suggest a transition marker

Suggest an evolutionary scenario

Identify new telos; account for the phenomenal aspect

Lists of characteristics for consciousness

Searle's (2004) List:

Features of consciousness

1. Qualitative nature
2. Ontological subjectivity (first person ontology) [for animals all is subjective…] It does not preclude epistemically objective science of that very subject matter
3. Unity
4. Intentionality [aboutness]
5. Mood (flavor- to be distinguished from emotion)
6. Attention
7. Pleasure/un-pleasure
8. Situatadness
9. Active and passive consciousness (voluntary/involuntary)
10. Gestalt structure (see 3); organizing perception into wholes; discriminating figures from backgrounds
11. Sense of self

Edelman's list (Edelman 2003 PNAS, 100:5520–5524)

General

1. Conscious states are unitary, integrated, and constructed by the brain.
2. They can be enormously diverse and differentiated.
3. They are temporally ordered, serial, and changeable.
4. They reflect binding of diverse modalities.
5. They have constructive properties including gestalt, closure, and phenomena of filling in.

Informational

1. They show intentionality with wide-ranging contents.
2. They have widespread access and associativity.
3. They have center periphery, surround, and fringe aspects.
4. They are subject to attentional modulation, from focal to diffuse.

Subjective

1. They reflect subjective feelings, qualia, phenomenality, mood, pleasure, and unpleasure.
2. They are concerned with situatedness and placement in the world.
3. They give rise to feelings of familiarity or its lack.

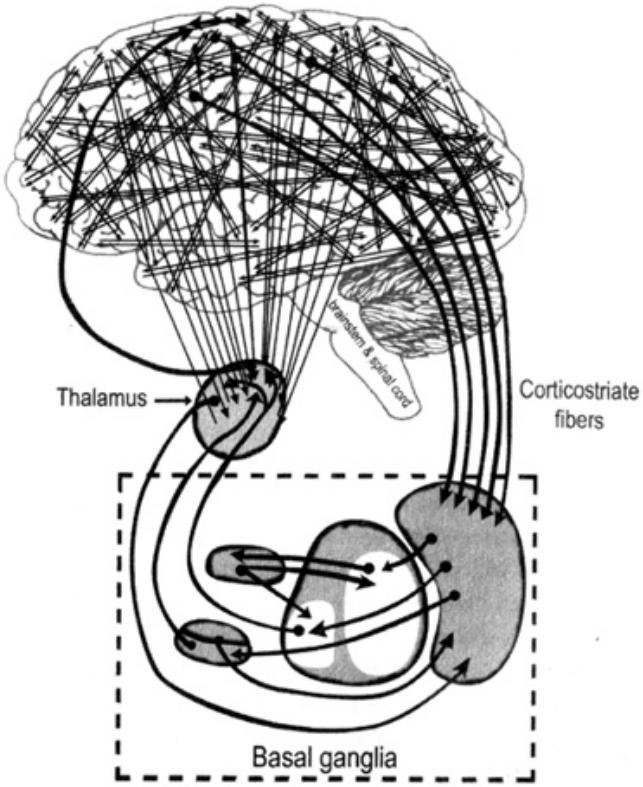
Table 2: Lists of defining characteristics of basic consciousness

Characteristics of mental states	Philosophers [a]	Neurobiologists [b]	Edelman [20]
Subjective experiences, values	Include subjective feelings, perception, thoughts, evaluations and moods	Values, emotions and goals	Reflect subjective feelings, qualia, phenomenality, mood, pleasure, and unpleasure. Give rise to feelings of familiarity or its lack
Unity, diversity and Self	Diverse yet unified states, with a qualitative "feel"; felt as “owned” by the subject, leading to the feeling that there is a unified owner, a “self”	Global activity and dynamically changing and differentiated brain states. Binding and unification, leading to both specific qualitatively distinct experiences and an experience of “self”	Are unitary, integrated, and constructed by the brain.They can be enormously diverse and differentiated; are temporally ordered, serial, and changeable. Reflect a binding of diverse modalities
Attentional modulation	Modulated by attention	Attentional modulation	Subject to attentional modulation, from focal to diffuse
Gestalt, plasticity and temporal thickness	Characterized by spatial and temporal gestalt structures that organize perception and affect into qualitatively distinct spatial wholes, having temporal “thickness”, or presentness	Show plasticity, metaplasticity and temporal thickness	Have constructive properties: gestalt, closure, and the phenomena of filling in. Have widespread access and associativity. Have center periphery, surround, and fringe aspects
Selection	Involve selection dynamics in the brain	Involve neural selection processes	Neural Darwinism processes are involved
Intentionality, transparency	Intentional [they are about something, directed towards objects and state of affairs]; refer to and project the effects of neurophysiological states onto internal bodily states and onto the external world, leading to the “transparency” of the world and the naïve self-evidence of the self	Are goal directed	Show intentionality with wide-ranging contents
Embodiment and situatedness	Are embodied and situated	Depend on the dynamic organization of the embodied nervous system	Are concerned with situatedness and placement in the world.

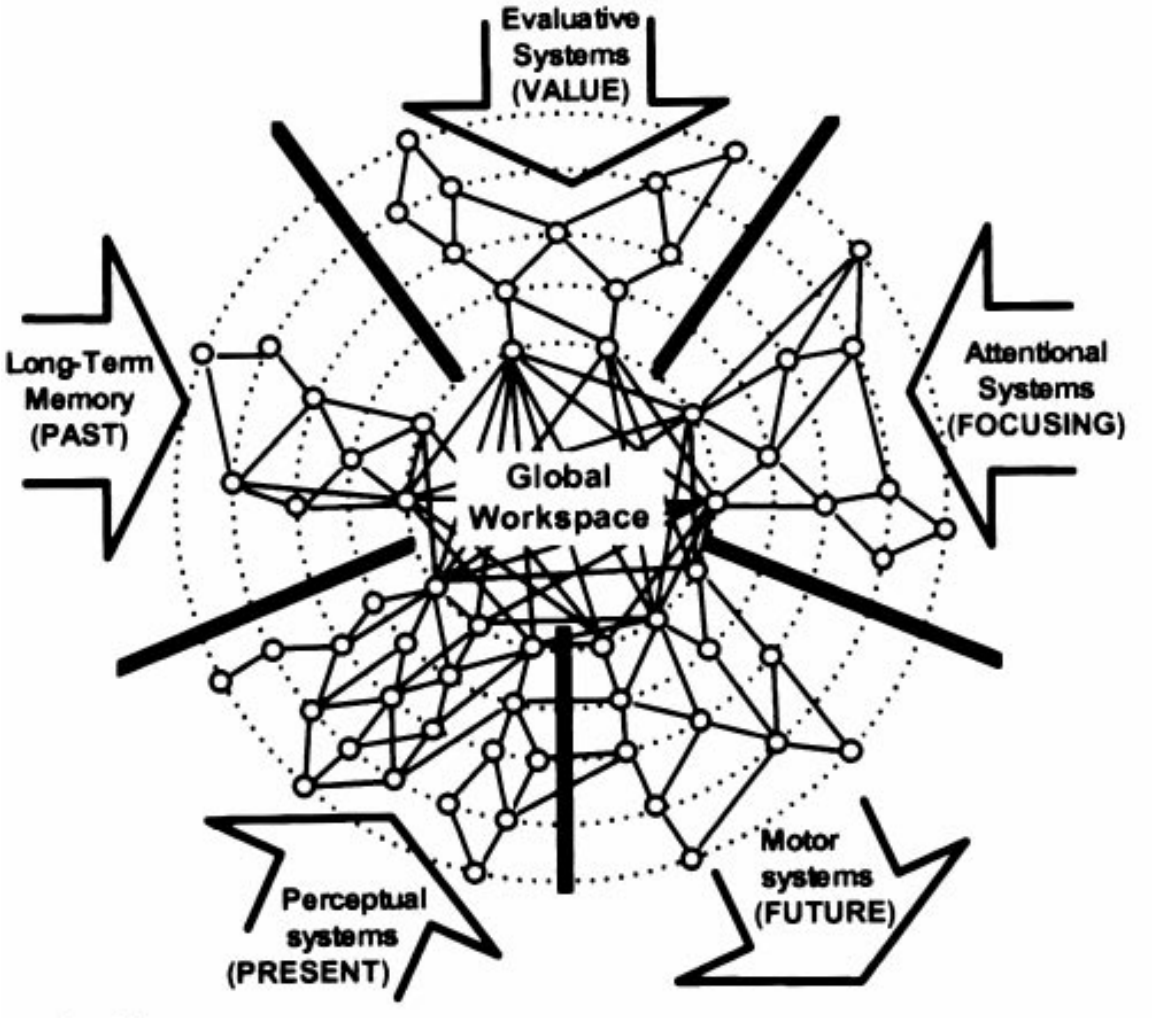
Organizational dynamics (e.g. Edelman's dynamic core):

Feedback and reentrant interactions, resulting in high Φ (Tononi's complexity measure, estimating both integration and differentiation); value systems; Extended present, neuronal selection.

There are other suggestions with different emphasis, but a lot of convergence (e.g. the Global Workspace of Baars, Changeux and Dehaene)



The dynamic core



Local processors have specialized operations, but when they access the GW they share information, hold it, and disemminate it; the information reaching the GW is conscious. [Based on Figure 1 in Dahaene, Kerszberg and Changeux (1998)

Who has it? The distribution problem

Some biologists think that experiencing (basic consciousness) cannot be attributed to non-humans (MacPhail); that it is special to birds and mammals (Gerald Edelman); that it is special to amniotes(Cabanac); that it exists in some invertebrates (Ginsburg and Jablonka); that it exists in every living being (Margulis).

What can we do????

A convincing transition marker can help! If we suggest a good transition marker we may (perhaps) be able to re-construct the enabling system that renders this marker realizable.

This is the secular-developmental version of Paley's argument: if we find several different long polymers with interesting organization in a new planet, we will need to assume that there was a machinery that generated them. What kind of machinery is it? A cell? What is the minimal machinery that generates the experiencing transition marker?

Suggested Transition Marker:

Experiencing emerged with the evolution of neural centralization and **flexible ("unlimited") associative learning** (UAL) in animals. UAL enabled animals to learn new relations on the basis of their ontogenetic history, and entailed new functions which altered their evolutionary trajectories.

We highlight three major functions of experiencing/UAL: discrimination, prediction and motivation. We argue that the integrated sensory states that are generated during UAL act as internal guides and selectors of new neural relations, new behaviors, and new ends. They lead to unitary, subjective and intentional internal dynamic states.

We argue that UAL presupposes an organizational dynamics that instantiates the list, leads to a new telos and points to evolutionary scenarios/s

Limited and unlimited heredity

John Maynard Smith and Eors Szathmary , following Ganti, suggested a distinction between limited and unlimited heredity as a criterion for life.

Limited heredity: the number of possible hereditary variants in the system is small, and therefore evolutionary change is extremely limited. Although systems with limited heredity are not fully living, they belong to the gray area between the nonliving and the living phases; big gray area

Unlimited heredity: the number of hereditary variations is practically unlimited and evolution is therefore open-ended; open ended heredity presupposes an autopoietic system

Limited and unlimited Learning

We suggest a parallel distinction: between limited learning and "unlimited" learning experiencing

Limited learning: the number of relations that can be formed and recalled during a lifetime is very small; most learning in non-associative.

Very limited sensory categorization. big gray area

"Unlimited" learning: the number of associations that can be formed and recalled within and between modalities during a lifetime far exceeds those that actually ever form (**there are, of course, many constraints**); sensory categorization is both rich and persistent

It is difficult to determine precisely at which level of functional sophistication associative learning becomes unlimited. We suggest that the transition has occurred when animals display both classical and operant conditioning and their basic modulations such as trace conditioning , reverse learning, latent learning, peak shift, and contextual learning – all of which are found in both invertebrates and vertebrates. (Perry et al 2013 Invertebrate learning and cognition: relating phenomena to neural substrate. WIRE Cog Sci 4(5):561–582.).

For UAL to exist, animals need to have a sophisticated enabling system: a central nervous system, a highly innervated body integrated at different levels, multiple feedback relations between sensory categorization programs, exploratory motor programs, and values systems. Just as unlimited heredity is not synonymous with life, but is a mark of organic-chemistry-based life in evolved complex biological systems, so too UAL is not equivalent to consciousness, because flexible learning can occur in non-conscious robots. UAL is, we suggest, a reliable marker of recognizable consciousness in evolved animals.

We suggest:

UAL and experiencing were **evolutionarily** isomorphic

Binding entails feedback between body and brain and leads to sensory categorization and (attempted) adaptive motor activity (embodied by definition; the brain does not feel or think. The animal feels and thinks)

Ontogenetically in extant animals, there can be experiencing with no UAL but no UAL without experiencing; **Evolutionarily** they emerged together

We believe that wide-ranging synaptic stabilization (required for UAL) and persistent interactions were selected in the context of binding among neural group that generated transient binding

Pavlovian and instrumental/operational AL were facets of the evolution of binding-related AL

Once synaptic UAL evolved, implicit AL learning and various types of unconscious integration became possible. Pre-UAL limited AL was non-conscious, but the integrated unconscious is derived.

UAL in animals entails experiencing

We have called any activated, distinct, learnt, minimally persistent overall sensory-motor state a **categorizing sensory state** (**CSS**). At the organism level, a CSS is a global dynamic sensory neurophysiological state—either a repulsor or an actively-maintained (metastable) attractor state.

We call this sensory state ‘categorizing’ for two reasons:

First, because the inputs that elicit it activate memory traces of other **inputs of the same type**, for example, inputs and memory traces related to tissue-damage.

Second, it is ‘categorizing’ because the inputs and traces will determine what **type of response** will occur, as memory traces of the motor responses to the inputs and the stimuli associated with the attainment of the attractor (e.g. relief from tissue damage) are activated.

Major Functions of UAL and Experiencing in Animals

The binding of stimuli makes it possible to **recognize and distinguish** between complex-combined stimuli (for such discrimination to be useful, long term-memory of newly bound connections is necessary) and to assign value to the combination.

Learning-dependent experiencing allows **prediction**: recognition and discrimination on the basis of *partial cues*; for the hungry animal contingent associations (e.g. vibrations) may be recognized and elicit an adaptive response, food-seeking.

Third, **it gives the animal clues as to *what to do*,** since some of the activated traces are associated with successful navigation towards the attractor-related stimuli (food, shelter and their contexts). The animal can now make an *educated guess*, based on its past experience. All these repulsor and attractor related stimuli are partially overlapping, dynamically changing aspects of the overall sensory-motor state of the animal, driving its activities.

Experiencing (phenomenal consciousness) is an overall, integrated, persistent, embodied, categorizing sensory state that had evolved as a facet of associative learning.

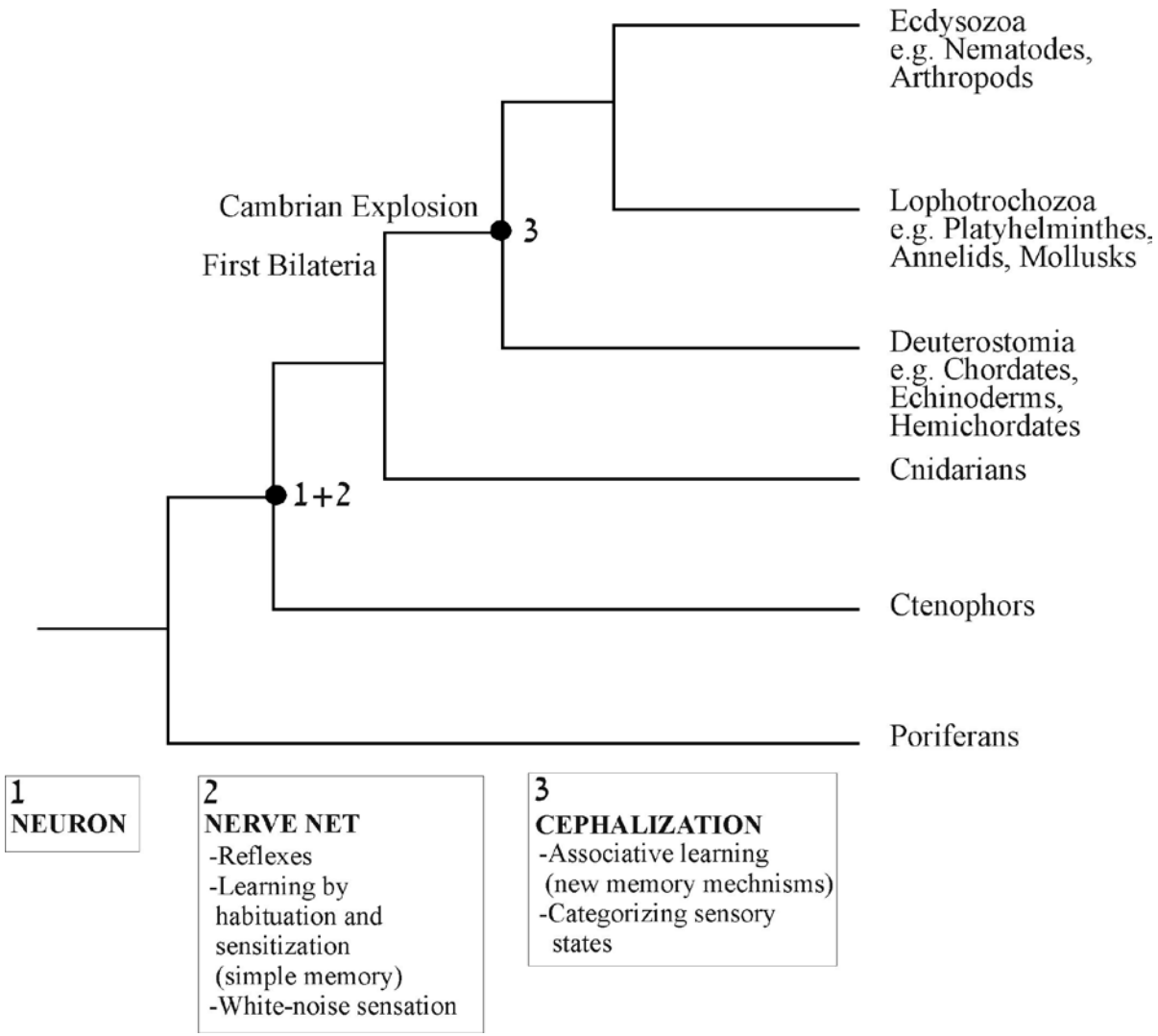
Its function is to categorize inputs and outputs, to motivate the animal, and allow predictions on the basis of partial cues that construct sensory-motor categories.

We suggest that UAL started evolving during the Cambrian

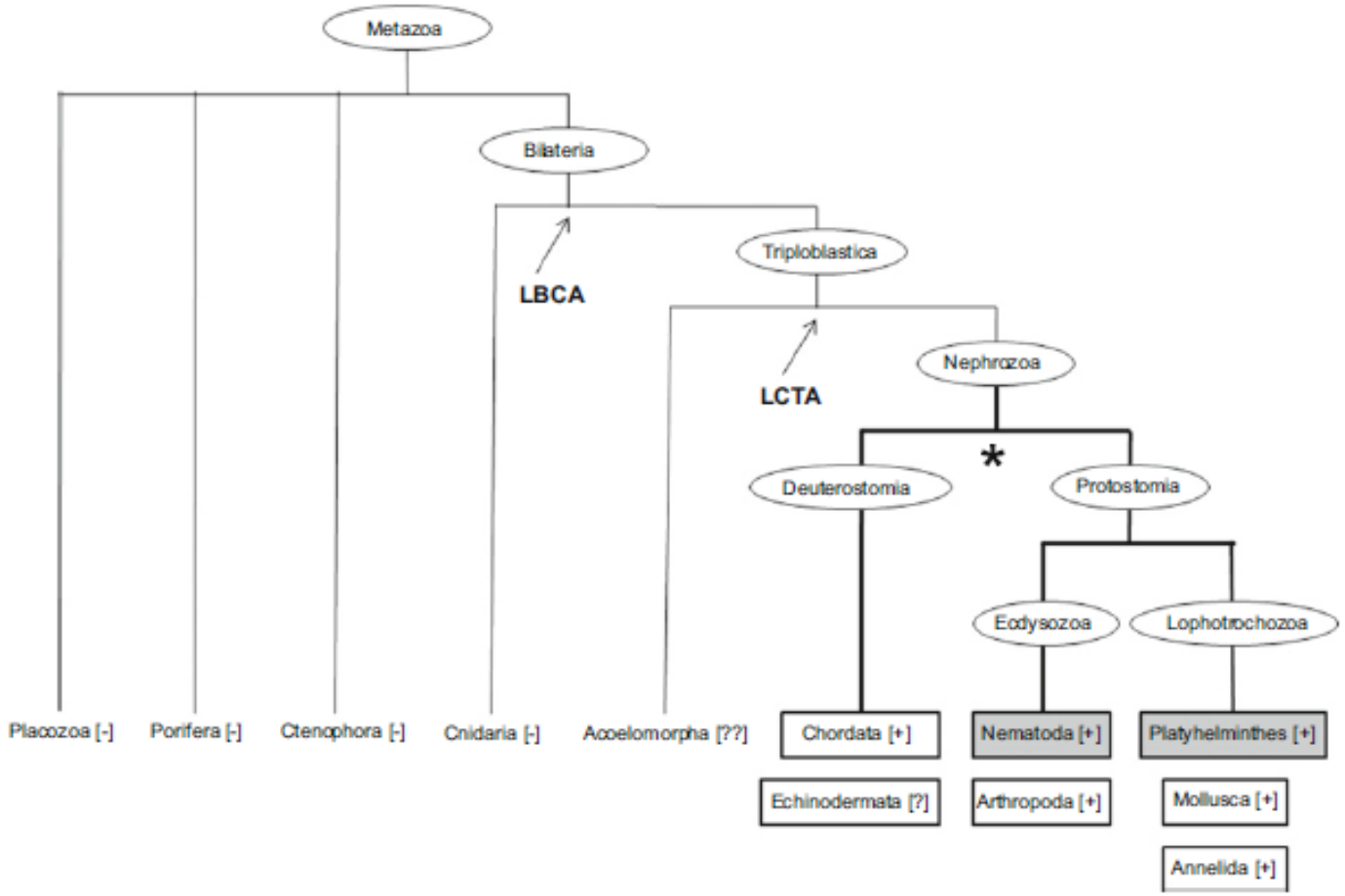
There is a gray area; does Aplysia experience? We need a dynamic model like the chemoton (and we do not have one)

Scenario

When? Why was it selected? what were the evolutionary effects?



All animals with UAL; all vertebrates and several groups of invertebrates; probably first started evolving during the Cambrian; parallel evolution.

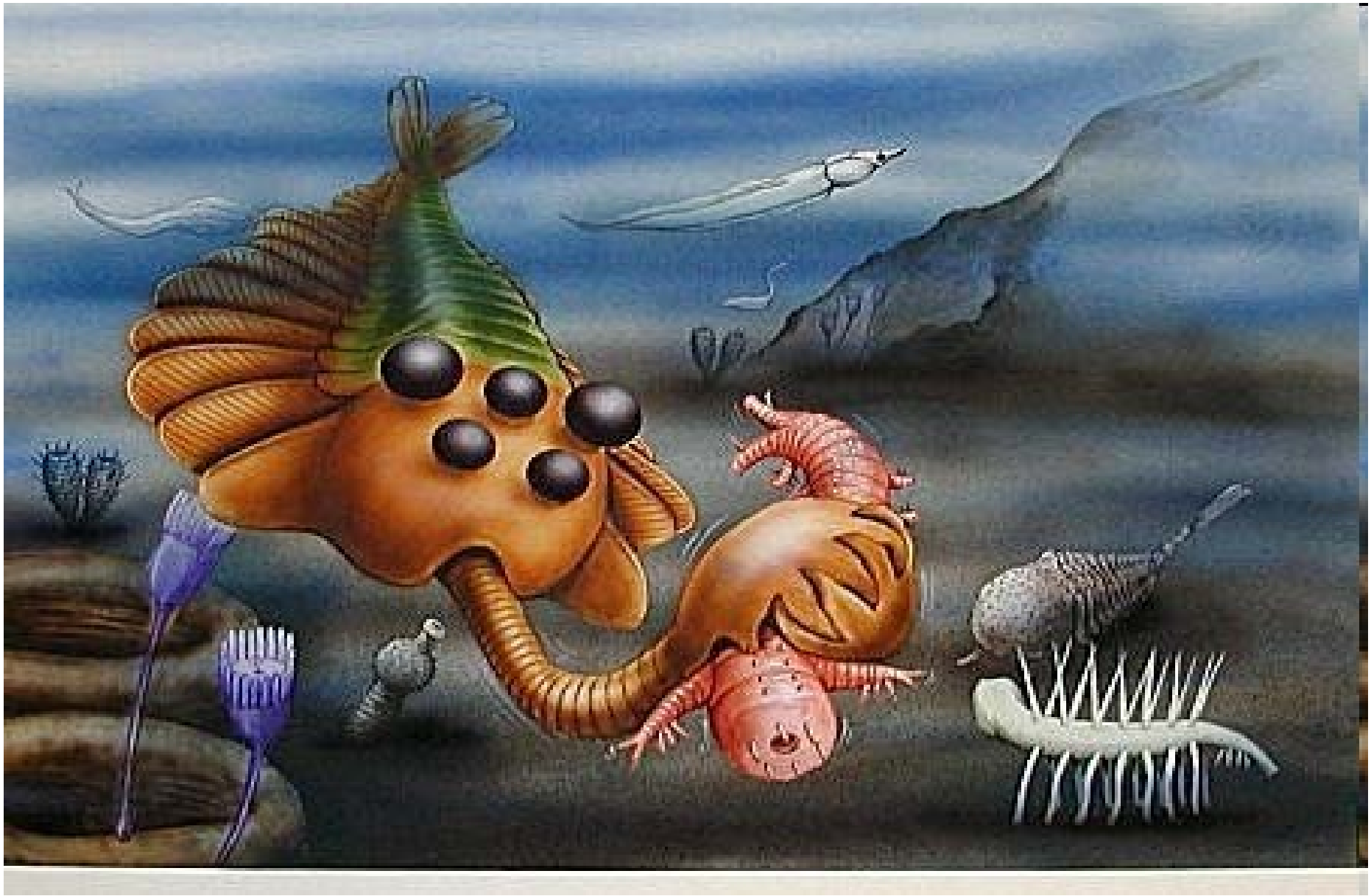


AL was the adaptability driver of the Cambrian explosion

The evolution of AL led to ecological arms races, evolution of sensory modalities, learning etc. through the Baldwin effect.

It led to ongoing stress (the smoke detector principle) and this enhanced generation of variations (until more efficient whole organisms stress responses evolved)

Predictions: the bifurcation leading to nephrozoans was characterized by the appearance of new neural/learning-specfic pfams and MiRs (preliminary results support this conjecture).



Living	**Experiencing**	**Symbolizing/ rationalizing**
Heredity	Memory (open-ended)	Cultural transmission (open ended)*
Development	Recall	Social reconstruction*
Evolution	Learning (open ended)	History (open ended)
Function	Need	Meaning
Information	Qualia	Knowledge
Fitness	Satisfaction (of needs)	Symbolic values

*involving symbolic representations; these two notions can be seen as different facets of cultural historical change.