

Roma, SS 2005

AUTOPOIESIS AND THE DEFINITION OF THE LIVING

(AN OVERVIEW OF THE ORIGINAL
BIOLOGICAL AUTOPOIESIS, AND ITS
RELATIONSHIP
WITH COGNITION)

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What is life?

THE MOST COMMON NOTION OF LIFE:

LIFE AT THE LEVEL OF POPULATION GROWTH
AS A GENETIC FLUX OF INFORMATION FROM
GENERATION TO GENERATION

WHICH IMPLIES THE HISTORICAL DIMENSION
OF EVOLUTION

THE THREAD WHICH LINKS ALL LIVING BEING
TO ONE ANOTHER FROM THE VERY BEGINNING
OF LIFE

**BUT ALSO:
LIFE AT THE INDIVIDUAL LEVEL,
LIFE HERE AND NOW
A DEFINITION WITHOUT THE CONSTRAINTS
OF GENETICS**

**Valid more in general
When you do not know or cannot establish the
genetic heritage
For synthetic systems
For unknown (e.g. exobiology) systems...**

a surprisingly acute definition given by F. Engels
(yes, the Engels of Karl Marx memory) written in 1894 (!):

*Life is the existence form of proteic structures,
and this existence form consists essentially in
the constant self-renewal of the chemical
components of these structures.*

This is indeed surprising, given the early time and the fact that Friedrich Engels certainly was not a great biologist, and acted in a time where nobody had a clear notion of what proteins really were.

M. Perret, who in the early fifties wrote a definition that was again taken by D. Bernal in **1965**:

Life is a potentially self-perpetuating system of linked organic reactions, catalyzed stepwise and almost isothermally by complex and specific organic catalysts which are themselves produced by the system.

Alexander I. Oparin gave a description of life based on six properties:

- (1) capability of the exchange of materials with the surrounding medium;**
- (2) capability of growth;**
- (3) capability of population growth (multiplication);**
- (4) capability of self-reproduction;**
- (5) capability of movement;**
- (6) capability of being excited.**

He also added some additional properties, such as the existence of a **membrane** (a cardinal principle for him); and the interdependency with the **milieu**

An important milestone in this regard is the so called “NASA definition of life”. This was originally simply an operational perspective used by the Exobiology Program within the National Aeronautics and Space Agency - a general working definition. However the community of people working in the origin of life uses it often as a definition of life. This working definition - used earlier by Horowitz and Miller (1962) - goes as follows (Joyce, 1994):

Life is a self-sustained chemical system capable of undergoing Darwinian evolution.

the adherents to the RNA-world would be satisfied by
a definition of minimal life summarized in the following terms:

*life appears at a population of RNA molecules
(a quasi-species) which is able to self-replicate
and to evolve in the process.*

..WHAT IS LIFE?

**THE STORY OF THE GREEN MAN
AND THE FARMER**

THE GAME OF THE TWO LISTS

LIST OF THE **LIVING**

The fly

The tree

The mule

The baby

The mushroom

The amoeba

LIST OF THE **NON-LIVING**

The radio

The automobile

The robot

The crystal

The moon

The computer

QUESTION: What discriminates the living from the non-living?

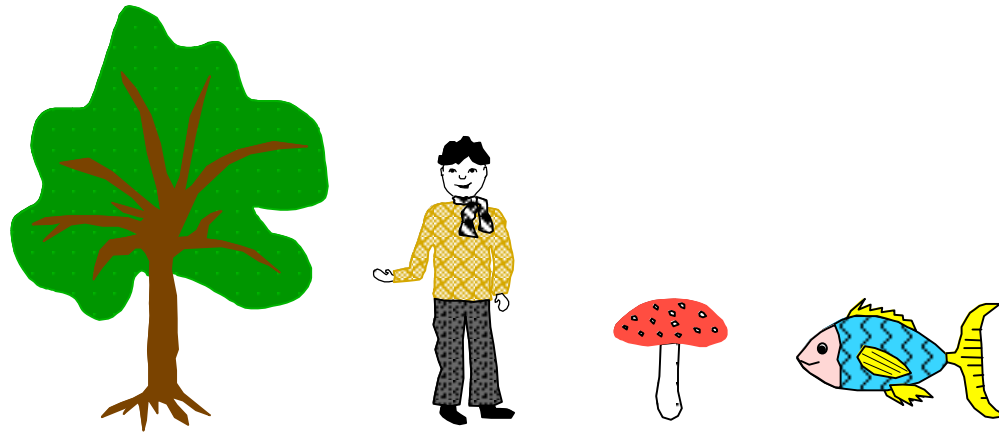
IN OTHER WORDS: What is the quality (or qualities) which is present in all members of the "living list" and which is not - and cannot - be present in any of the elements of the "non-living" list?

(

What is life ?

**A common sense definition at individual level
(LIFE " HERE AND NOW ")**

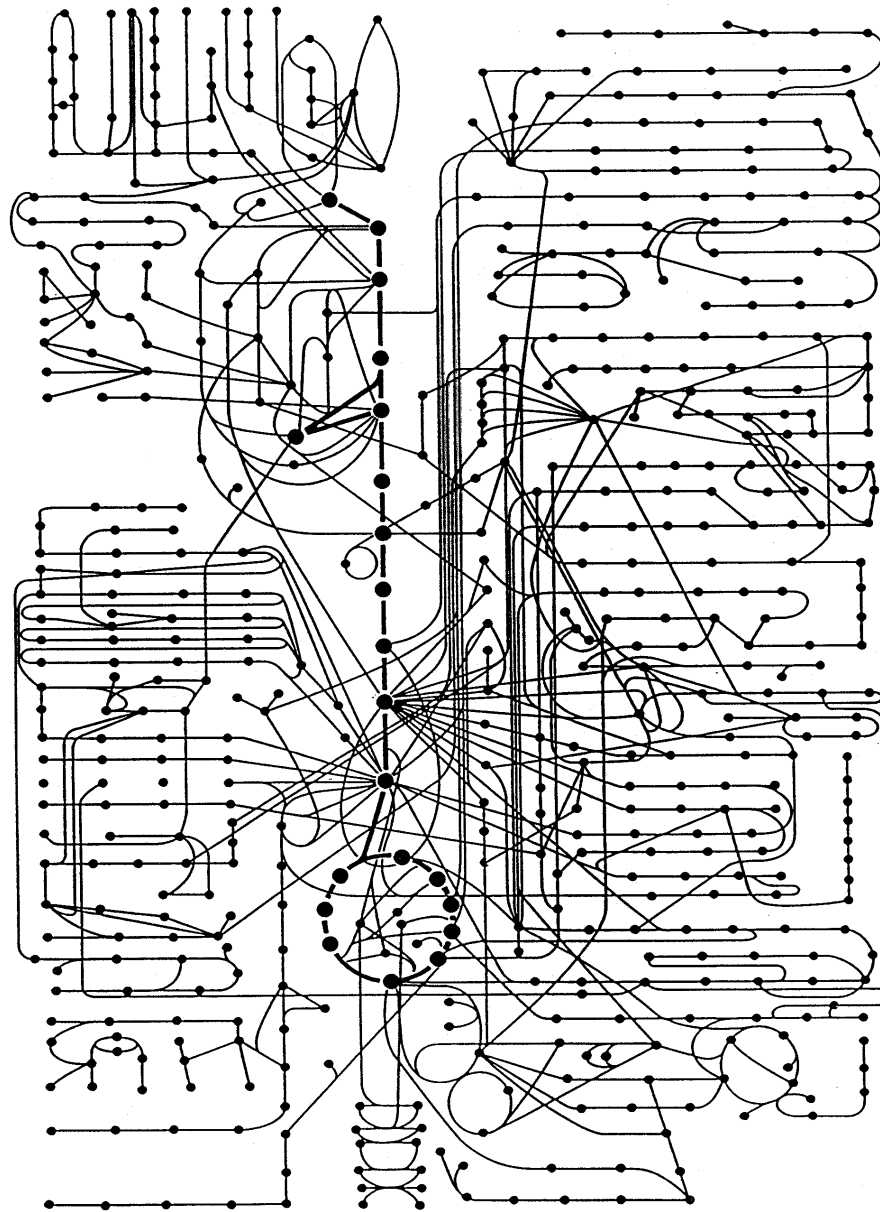
A living system is a system defined by a physical boundary which allows the assimilation of nutrients / energy from the outside, and which is able to self-maintenance and self-generation owing to the activity of the system from within the boundary.



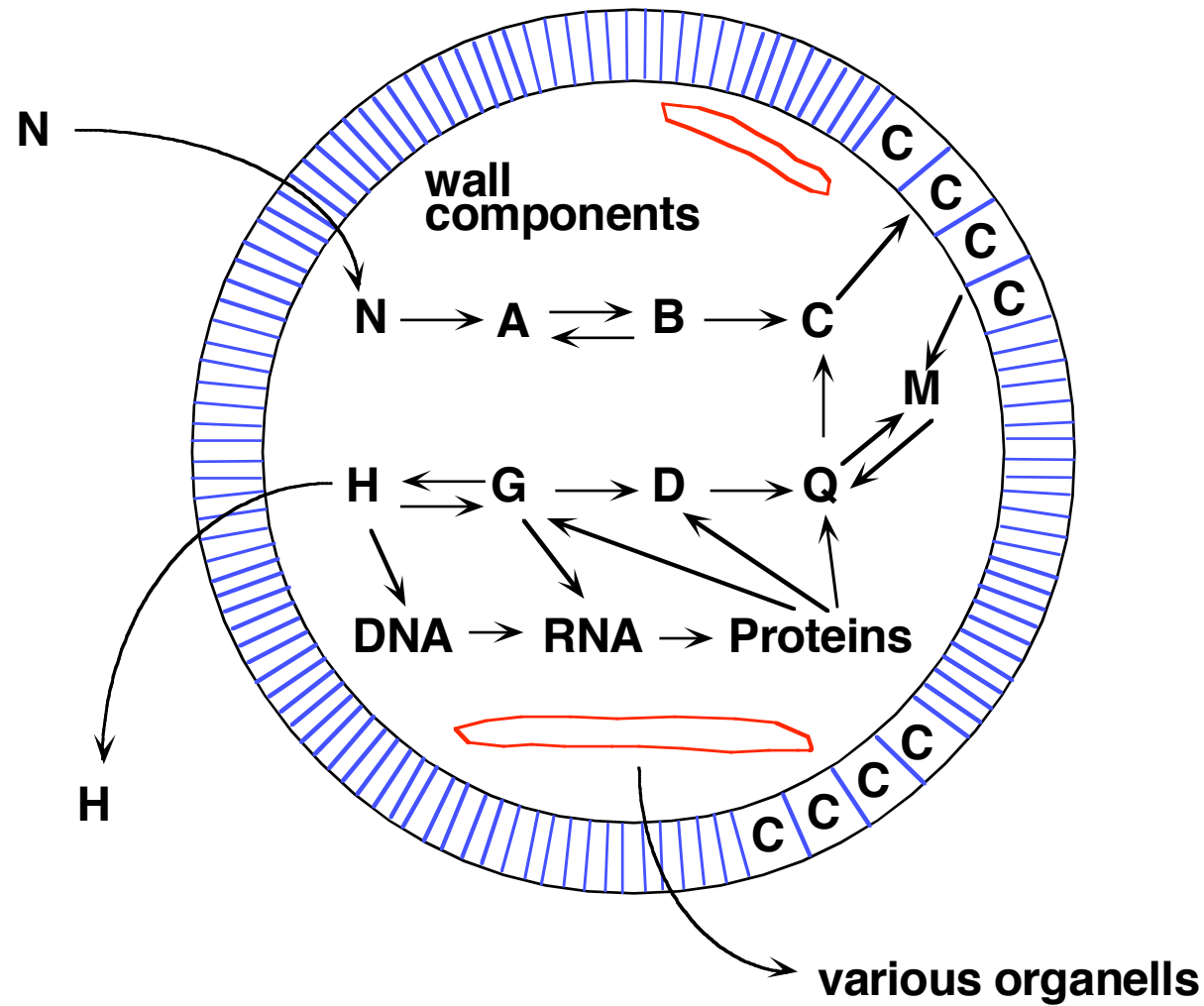
**Notice that for this first-level definition no scientific knowledge on cellular structure or molecular biology is needed.
Notice also that self-reproduction or evolution are at this first-level (life here and now) not necessary.**



A maze illustrating the chemical reactions that interconvert small molecules in cells.



NUTRIENTS / ENERGY



how does a cell work ?

- a semipermeable membrane discriminates “self” from “non-self” & allows energy / nutrients in and byproducts out
- and determines a particular microenvironment which induces a specific reaction network
- by which several components are transformed and continuously replaced
- so that the cell maintains its own identity (“self”) in the face of an on-going series of transformations

THE CELL MAIN ACTIVITY IS
TO MAINTAIN IST OWN IDENTITY
(SELF-MAINTENANCE)
DESPITE THE ENORMOUS NUMBER
OF TRANSFORMATIONS
AND THE CELL DOES SO
THANKS TO A PROCESS OF
RE-GENERATION FROM WITHIN

The cellular definition of life:

**A system spatially defined by a
boundary of its own making
and that is self-sustaining
by re-generating all system's components
from the inside**

autopoietic unity = minimal life

" an autopoietic unity is able to self-generate owing to a reaction network taking place within its own boundary "

(the reaction network makes all components of the unit, including the boundary.)

Varela et al., Biosystems, 5 (1974) 187

" self-generate" — [self-maintenance
or
self-reproduction

in general

self-reproduction ≠ self-replication

AUTO POIESIS

(SELF PRODUCING)

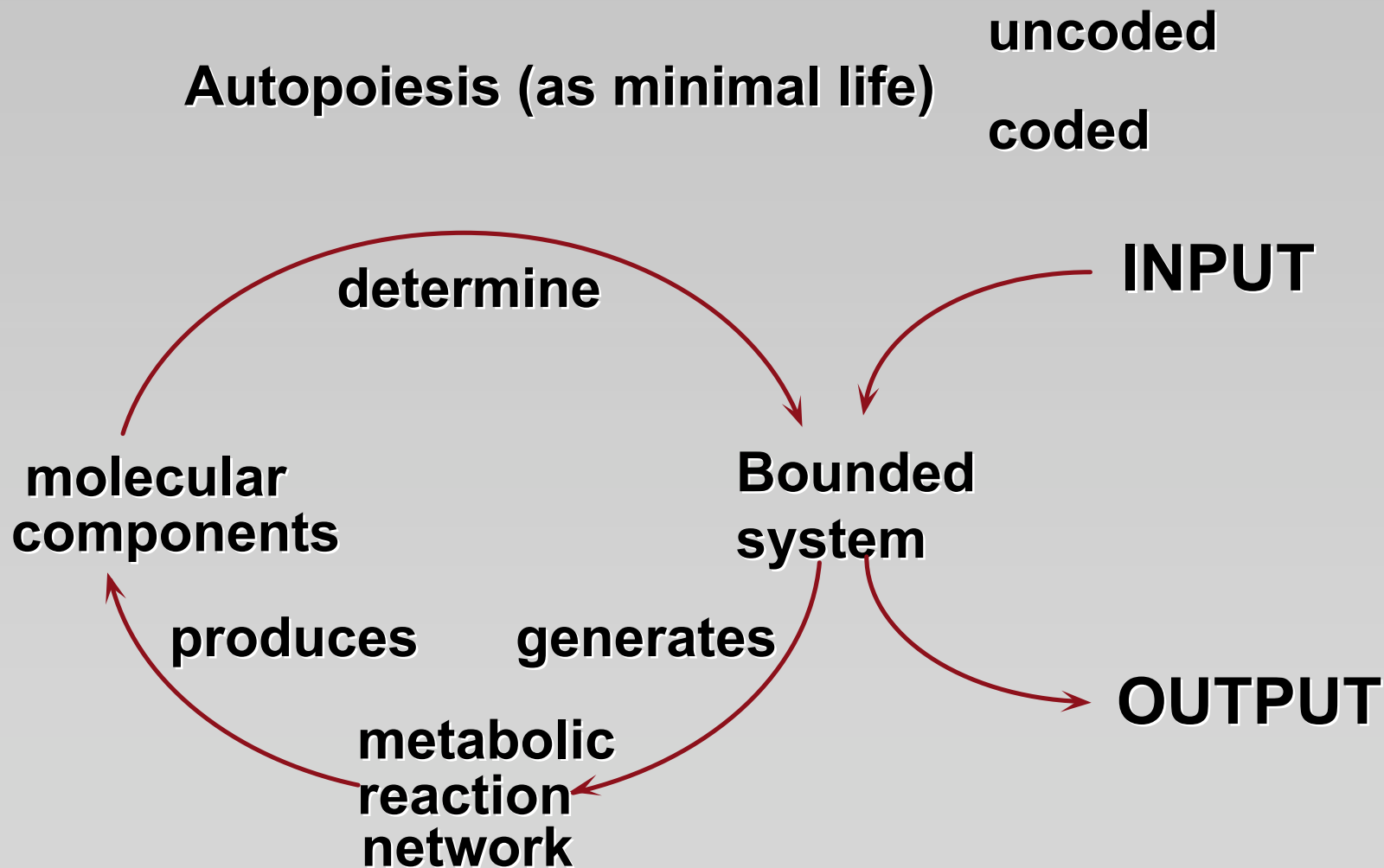
Maturana & Varela, 1970

- **Varela, Maturana, Uribe**
Biosystems 5 (1974) 187
- **F. Varela, Principles of biological autonomy**
north Holland 1979
- **G. Fleischhaker**
Biosystems 22 (1988) 37
- **P.L. Luisi in "Thinking about Biology"**
W. Stein + F. Varela editors
Addison-Wesley, 1993

**A DISCOVERY: THE CELLULAR
(AUTOPOIETIC)
DEFINITION OF LIFE
ALSO APPLIES**

**TO MULTICELLULAR,
MACROSCOPIC
LIFE**

Autopoiesis is the most general pattern of minimal life. It does not specify the actual structures and their mechanistic processes.



nutrienti / energia

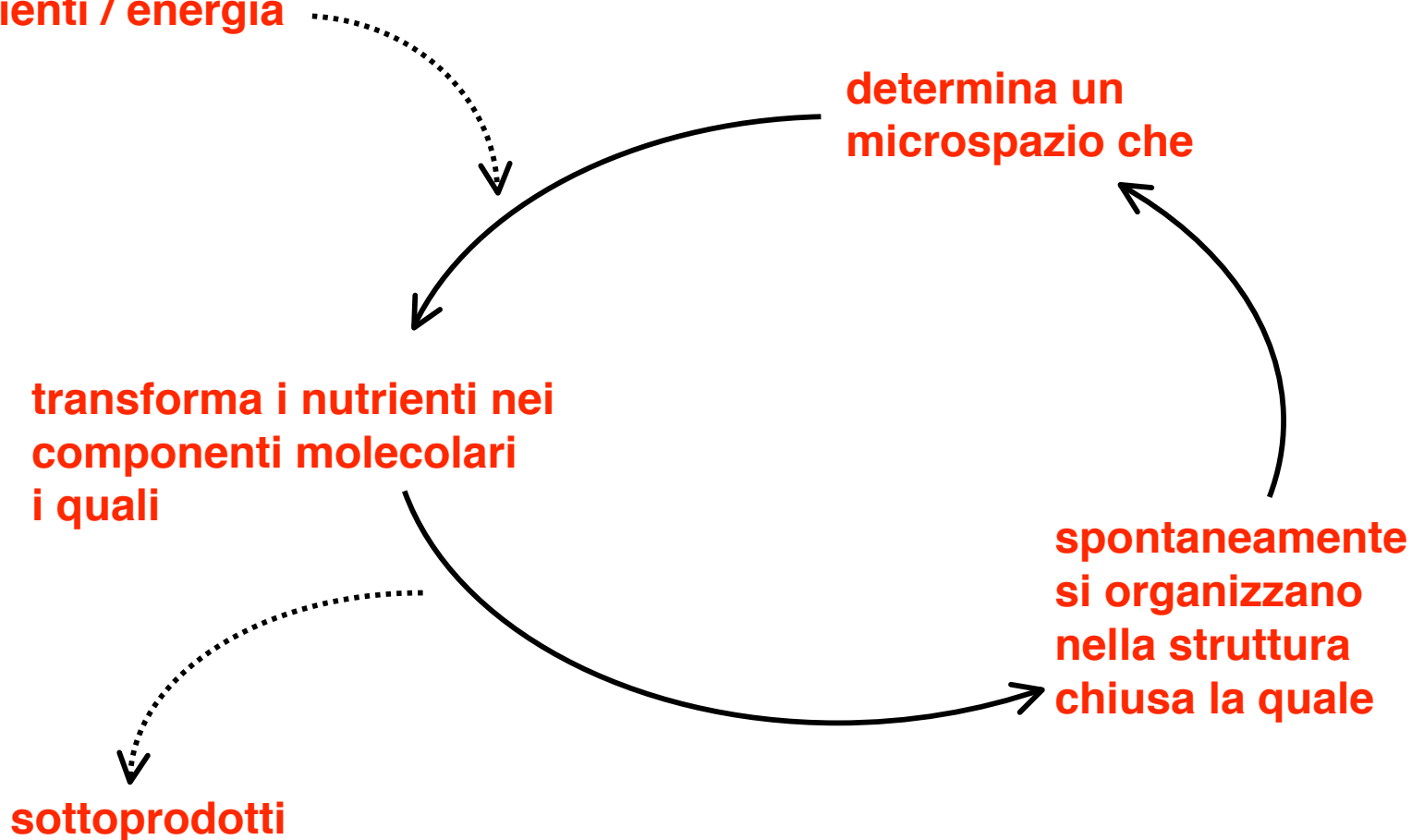
**determina un
microspazio che**

**trasforma i nutrienti nei
componenti molecolari
i quali**

**spontaneamente
si organizzano
nella struttura
chiusa la quale**

sottoprodotti

LA DEFINIZIONE CICLICA
DEL "SELF"
(...la vita ubbidisce ad una logica ciclica...)



**self-maintenance from within,
due to a dynamic network of
interactions,
which are defined and
constructed
by the system itself"**

But ! ...

if something exhibits autopoietic production, that "something" is living.

Autopoiesis is a **minimal definition**, in that autopoietic organization is the one phenomenon which is common to every member of life's kingdoms on earth - and yet does not exist among the constituents of their non-living surroundings.

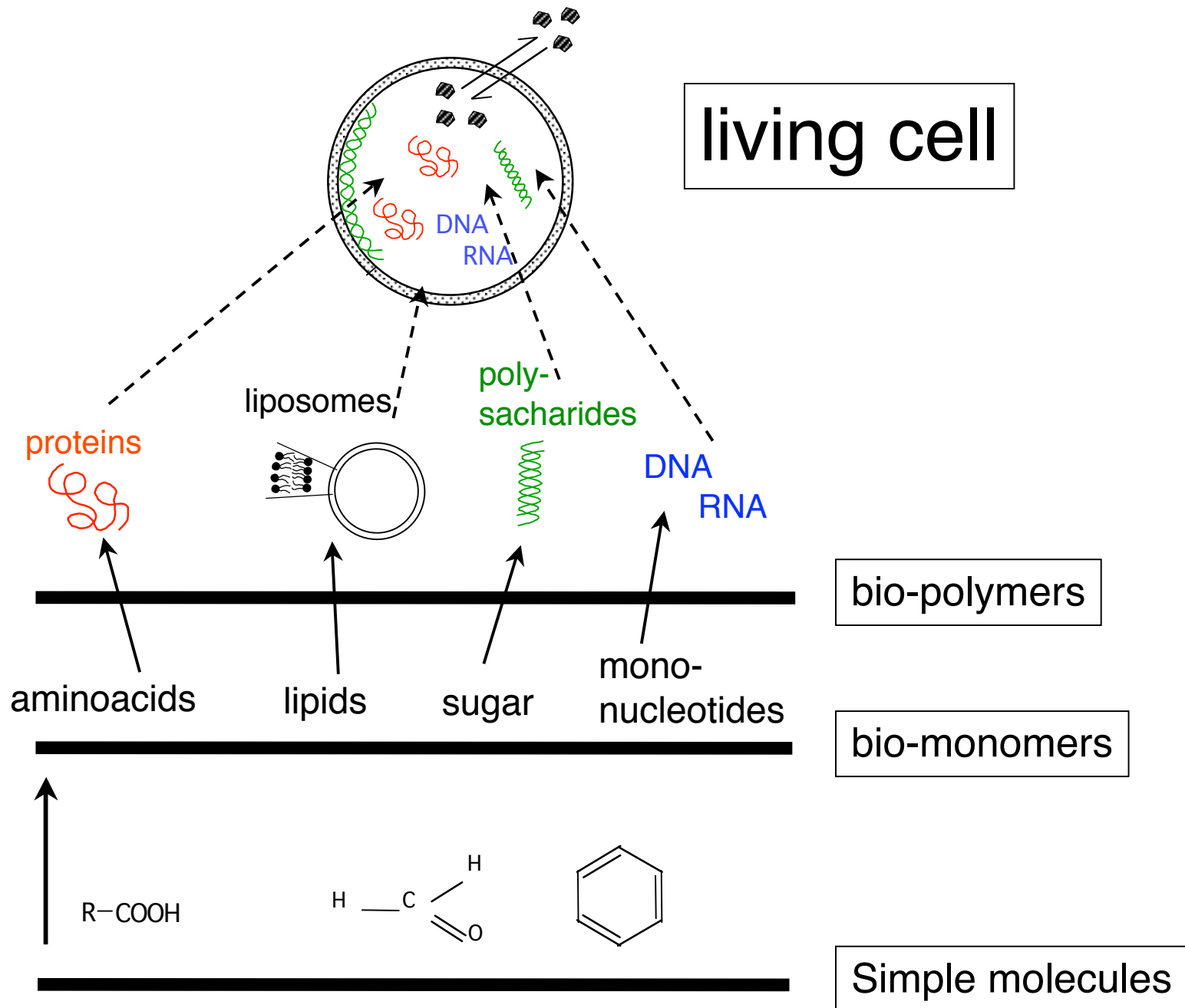
... if some hitherto inconceivable entity were to exhibit autopoietic organization, that alone would suffice to distinguish it as living ...

Fleischaker (1990)

Life is an emergent property:

**the components (nucleic acids,
proteins, lipids, sugars etc)
are per se' not living;**

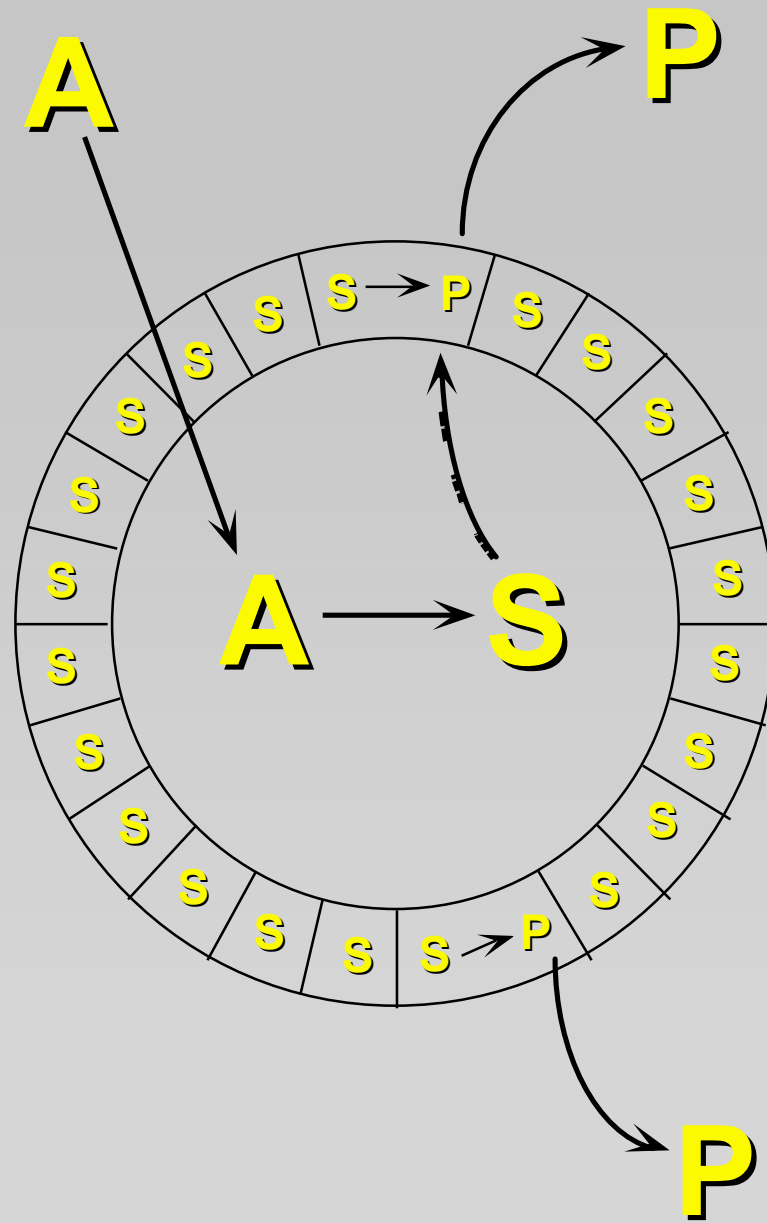
**When they are assembled together
in a particular space/time
structure, then life emerges**



The paradigm of molecular science:

The phenomenological world-including life-is constituted solely by molecules and their dynamic interactions

„dynamic interactions“ may involve however a very complex set of processes and properties-



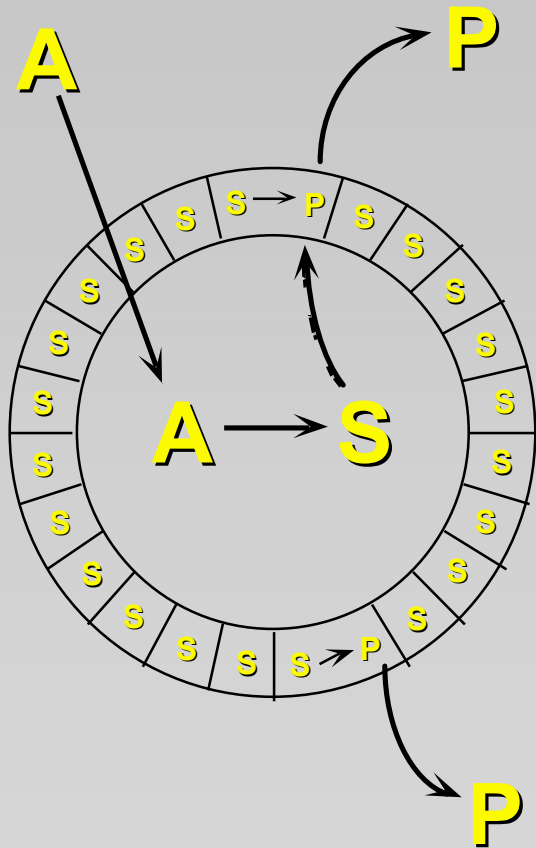
AUTO POIESIS

(SELF PRODUCING)

Maturana & Varela, 1970 →

- Varela, Maturana, Uribe
Biosystems 5 (1974) 187
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autonomy, north Holland
1979
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THE MINIMAL AUTOPOIETIC SYSTEM



$$v_{\text{gen}} = \frac{d[S]}{dt} \quad ; \quad v_{\text{dec}} = -\frac{d[S]}{dt}$$

if $v_{\text{gen}} = v_{\text{dec}}$ **homeostasis**

if $v_{\text{gen}} > v_{\text{dec}}$ **self - reproduction**

CHEMICAL AUTOPOIESIS:

**FOR SELF-REPRODUCTION OF CLOSED
VESICULAR STRUCTURES, SEE**

NATURE 357 (1992) 57; 409 (2001) 387

J. AMER.CHEM.SOC. 98, (1994) 1160; 117 (1995) 1299

CHEM.& BIOLOGY 3 (1996) 277

**FOR MODELS OF SELF-MAINTENANCE
SEE:**

ANGEW. CHEMIE 40 (2001) 199

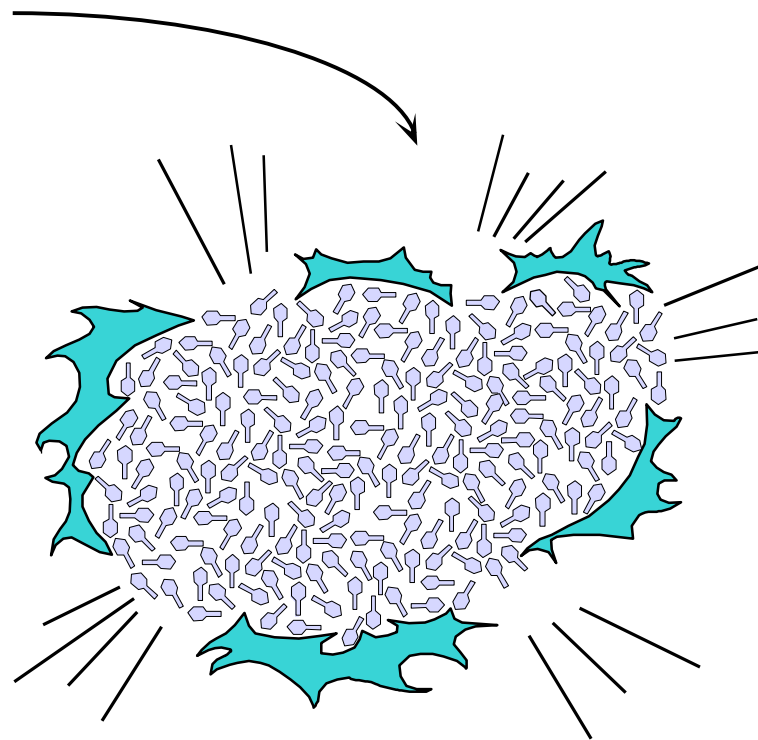
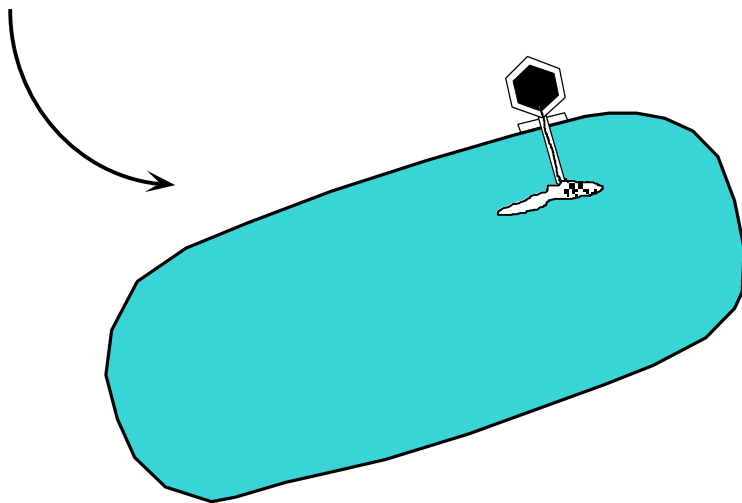
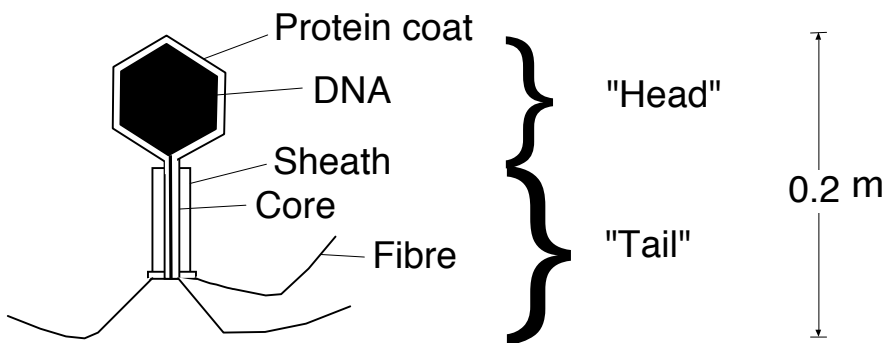
three criteria of autopoiesis

applications of these criteria permits one to discriminate between the living and the non-living. Only if you answer yes three times is the system autopoietic and therefore living.

1. ***Self-boundary:***
Does the system have a boundary of its own making?
2. ***Self-maintenance:***
Is the system capable of maintaining its own identity via dynamic processes, i.e. those components which are being used up are made anew by the system itself?
3. ***Self-generation:***
does this happen throughout a network of reactions which are generated by the system itself?

**Consider a growing crystal:
Is it living?**

Apply the criteria of autopoiesis



CONCEPTS RELATED TO AUTOPOIESIS

**BOUNDARY
ORGANIZATION AND STRUCTURE
EMERGENCE
HOMEOSTASIS**

**SELF-MAINTENANCE; SELF-GENERATION
AUTONOMY; SELF-IDENTITY**

**CODED AND UNCODED LIFE
DISSIPATIVE STRUCTURES**

**STRUCTURAL COUPLING
SYSTEM'S HISTORY
SOCIAL AUTOPOIESIS**

**COGNITION
MIND AND MATTER
CONSCIOUSNESS**

what autopoiesis does not contain :

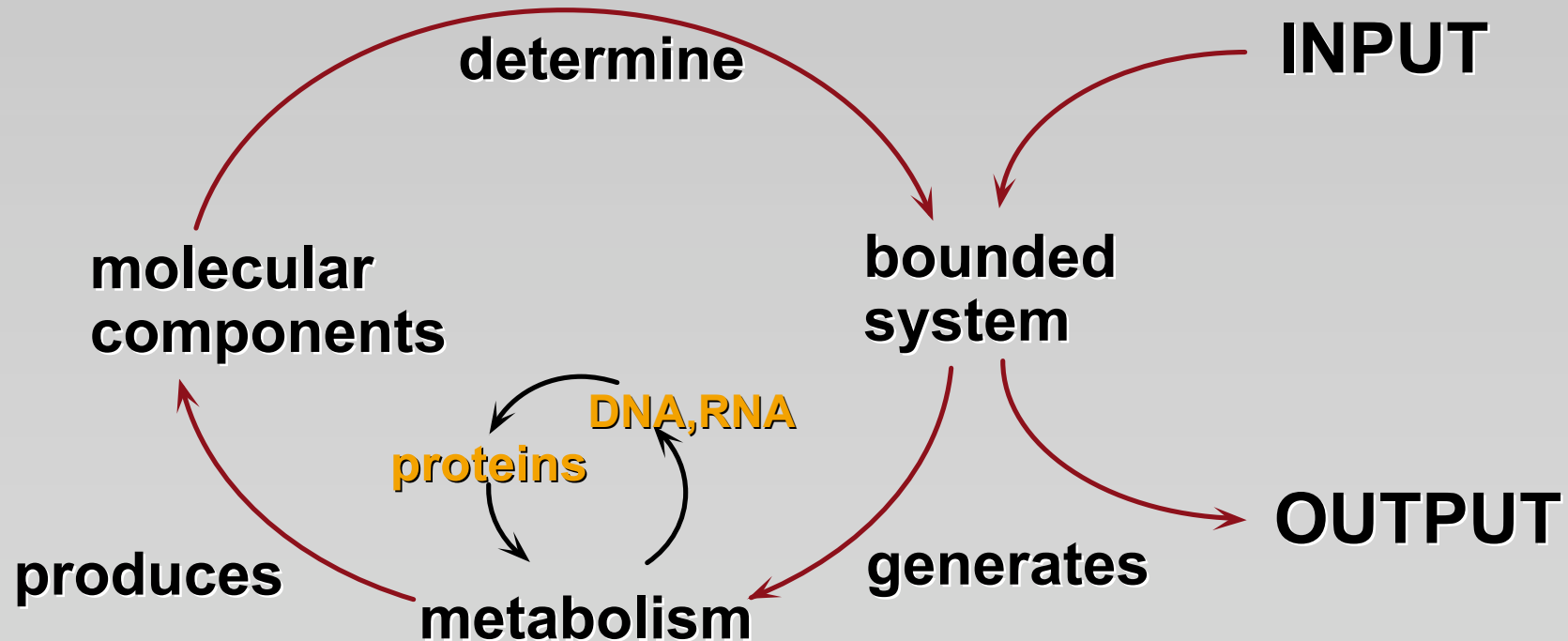
origin of life
evolution / mutation

- 1) ...because autopoiesis is primarily interested in defining life here & now
- 2) and also because the above properties are easily implemented in an actual operating autopoietic system.

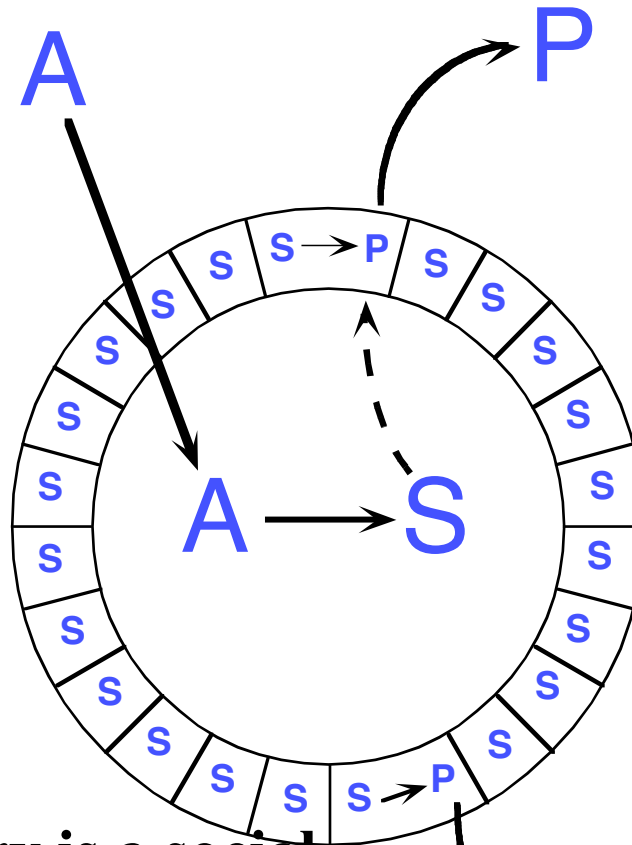
Notabene :
cellular evolution is a consequence
of life - not its cause....
The autopoietic unit must precede
its own evolution.

LIFE IS

a system confined by a chemical boundary and which contains a network of nucleic acid - protein - based reactions which is able to transform external energy / nutrients into self-maintenance and self-generation.

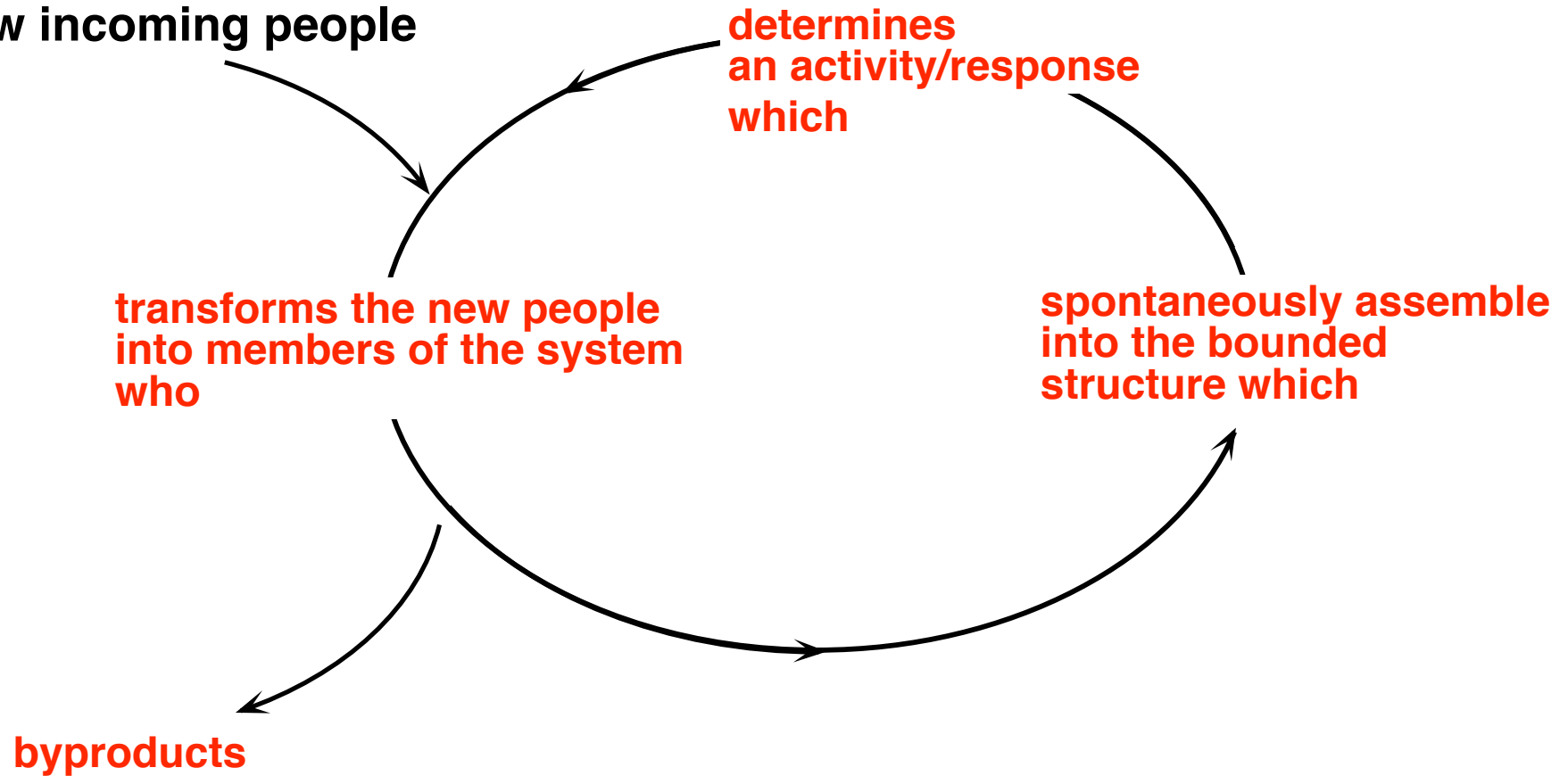


Towards social autopoiesis



If the boundary is a social structure(a city, a party, an hospital...)
and **A** a new person who becomes
a member (**S**)....

New incoming people

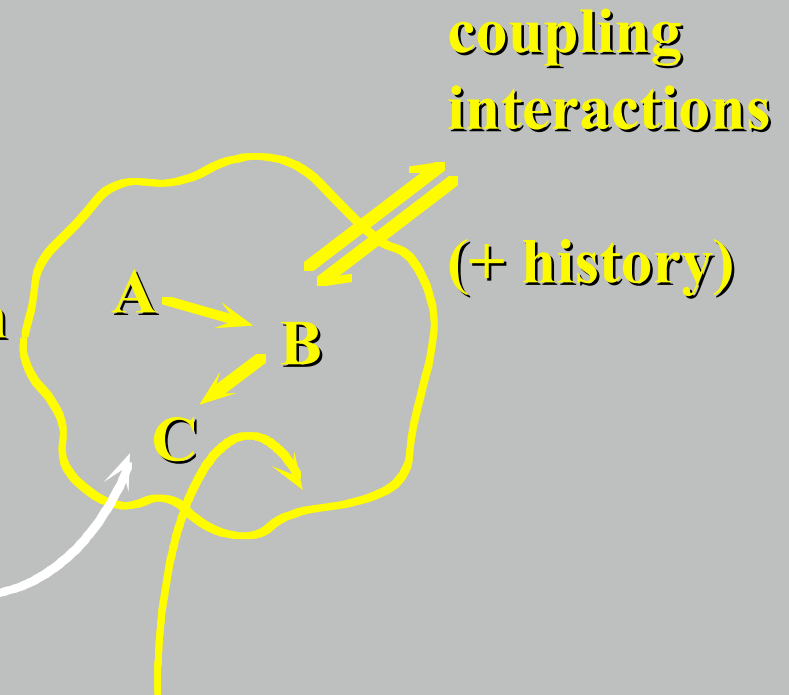


Towards social autopoiesis

SOCIAL AUTOPOIESIS (?)

- a nation
- a political party
- religion
- family
- one city
- any social system ?
- Gaia

} structure
&
organization



(substructures or individuals)
which are being reproduced
from within

**boundary defined
(and created) from within**

**" self-maintenance from within, due to a
dynamic network of interactions, which are
defined and constructed by the system itself "**

**HOW DO YOU PROCEED
EXPERIMENTALLY**

**FOR CONSTRUCTING
IN THE LABORATORY**

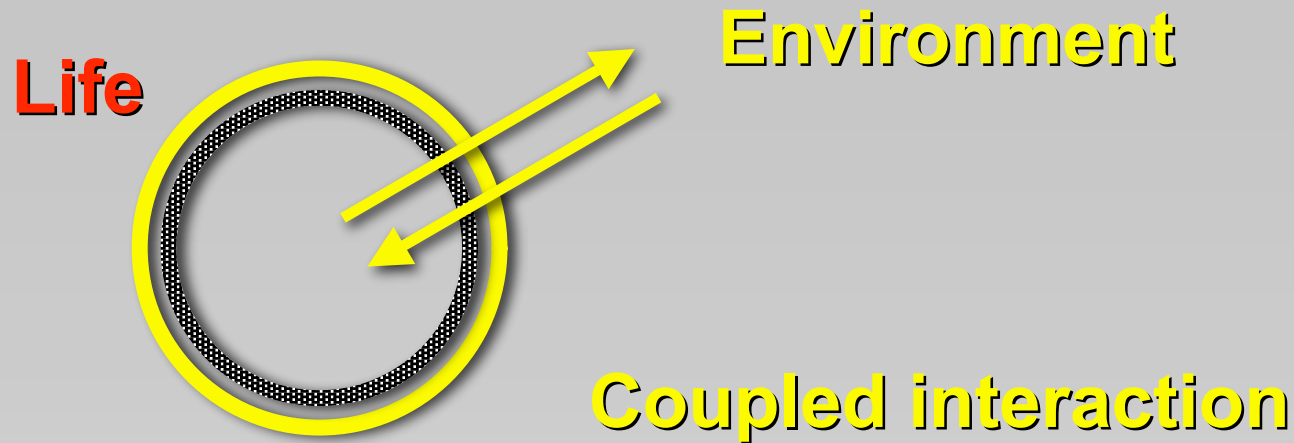
**AN AUTOPOIETIC SYSTEM
AS A CELLMODEL?**

**Liposomes, as closed spherical
bilayers, are considered the most
likely precursors of early living cells
(protocells)**

LIPOSOMES ARE JUST TINY SOAP BUBBLES

What is life?

What is cognition?



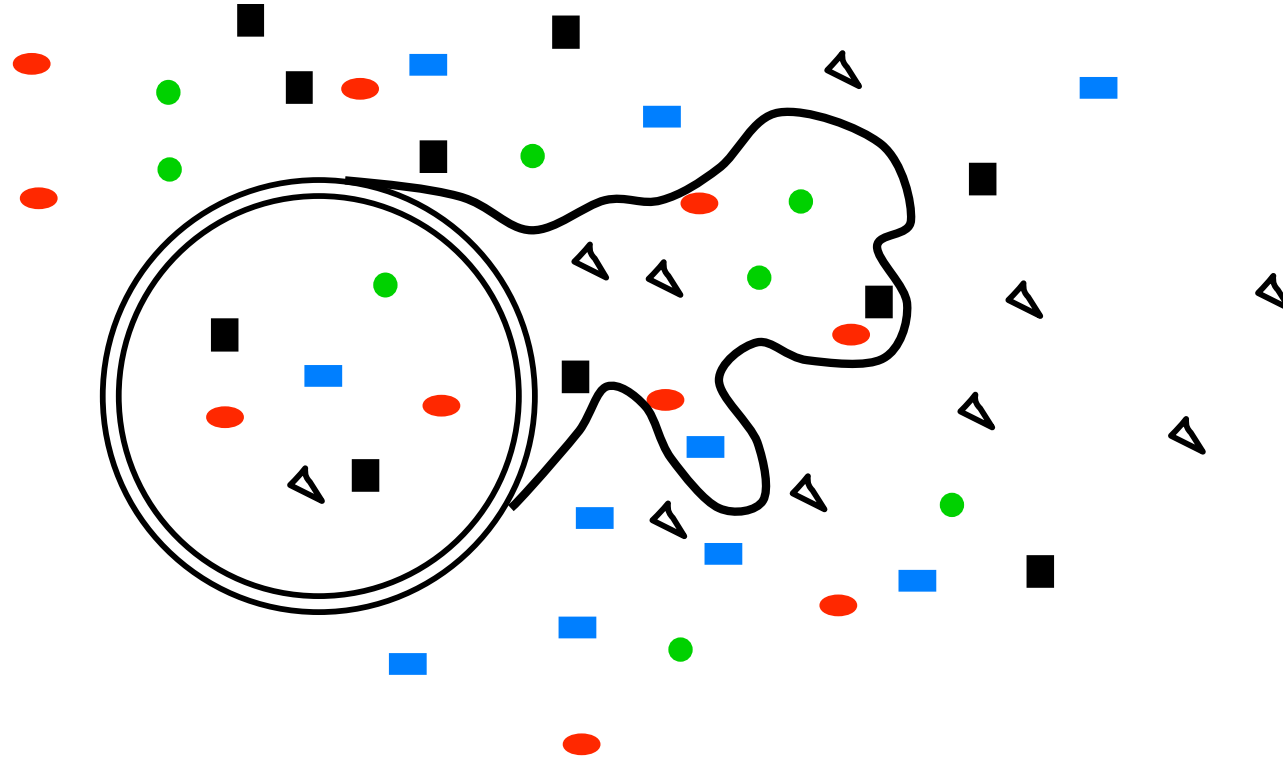
SANTIAGO THEORY :

**Life = interaction
with the environment → cognition**

..A HISTORY OF COUPLING INTERACTIONS FROM WHICH THE COGNITIVE DOMAIN IS CONSTITUTED NEITHER INTERNALLY (A SOLIPSISTIC VIEW) NOR EXTERNALLY (THE TRADITIONAL VIEW).

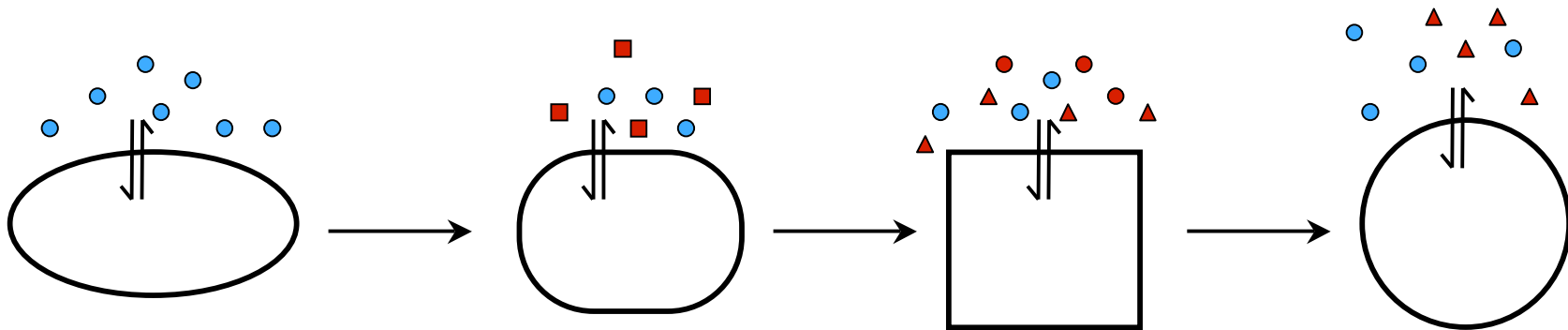
THE ALTERNATIVE THAT ELIMINATES THESE TWO EXTREMES IS BASED ON A CO-DEFINITION BETWEEN THE INTERNAL AND EXTERNAL SYSTEM. THIS IS THE NOTION OF **ENACTION.**

ENACTING MEANS TO MAKE EMERGE



the organism creates from the environment
its own world
(→ cognition, → enacting)

evolution:
the history of coupling interactions



a living organism as the
depository of a long history
of adaptive changes

**...it is the organism itself,
with its receptors, nervous centers,
movement of the organs,
which chooses the stimuli,
to which it is sensitive.**

**The environment comes out
of the world with the actualization
of the organism's essence...**

**Merleau –Ponty, „The structure
Of Behaviour“**





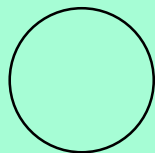
**THE MAIN ASSUMPTION OF THE SANTIAGO SCHOOL
IS THE EQUIVALENCE BETWEEN THE PROCESS
OF COGNITION
AND THE PROCESS OF LIFE**

**ACCORDING TO THIS VIEW, BRAIN IS NOT
NECESSARY FOR COGNITION: BACTERIA AND
PLANTS DO NOT HAVE A BRAIN,
THEY POSSESS HOWEVER COGNITIVE CAPABILITY**

ON THE BASIS OF THE EQUIVALENCE
BETWEEN LIVING STRUCTURE AND
THE ACT OF COGNITION, THE OLD
CARTESIAN
SEPARATION BETWEEN MATTER AND
SPIRIT
IS SUPERSEDED.

THESE TWO CATEGORIES
ARE NO LONGER DISTINCT ENTITIES,
THEY ARE TWO FACES OF THE SAME
PHENOMENON:
LIFE

autopoietic
unit



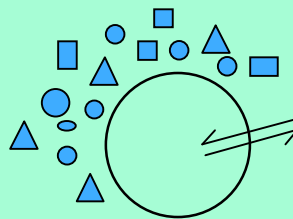
co-emergence

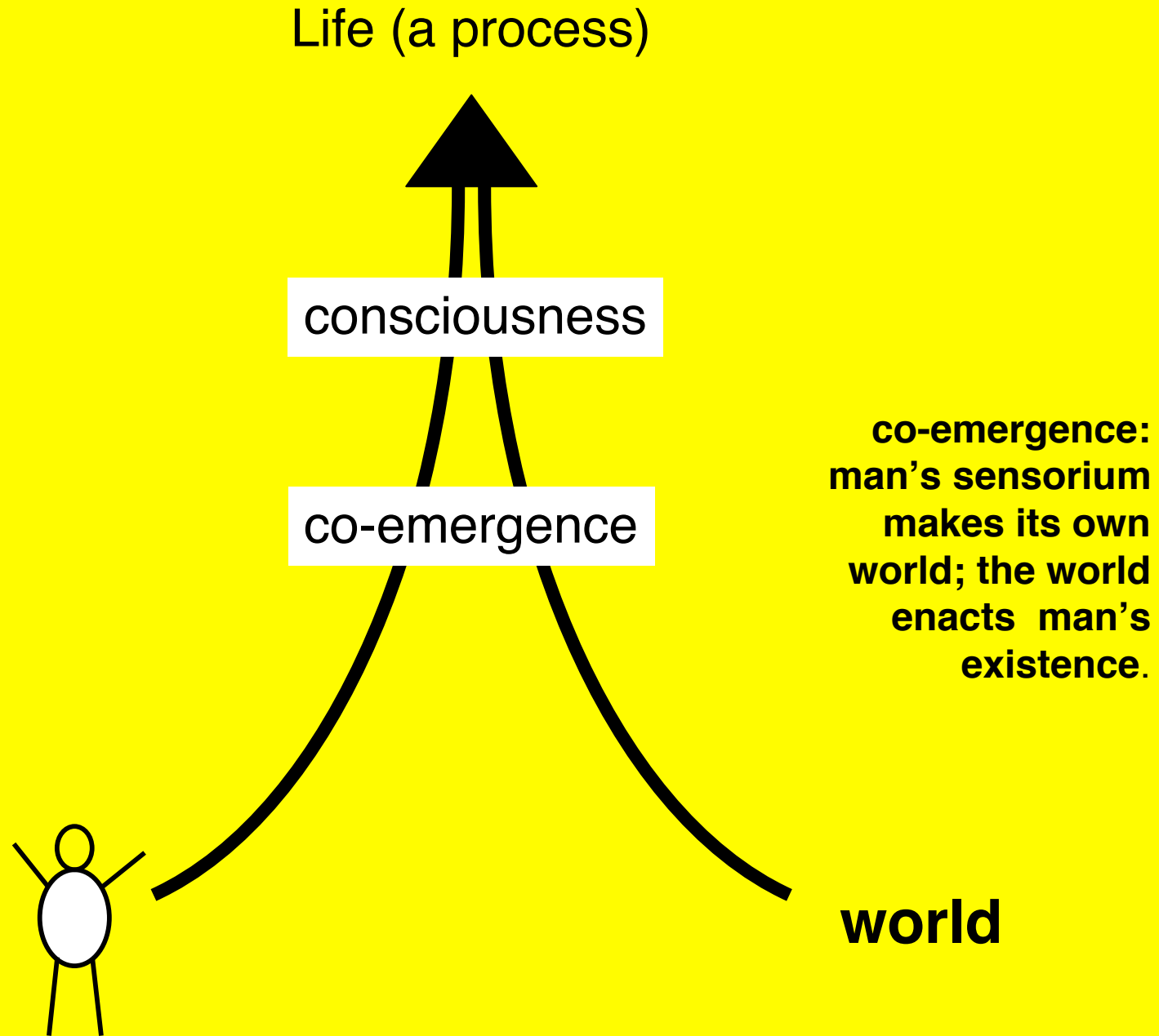
cognition

Life (a process)

environment

the autopoietic structure
selects out from the
environment its own
world; the environment
elicits (enacts) the
organism's being

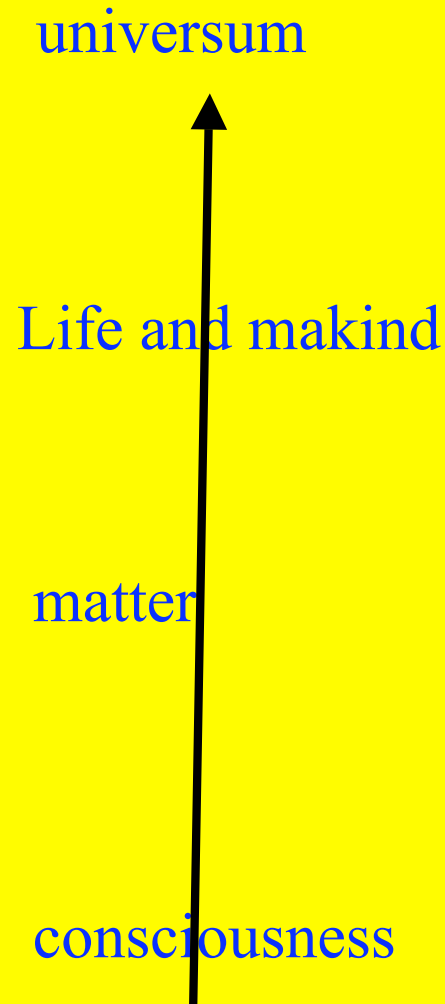
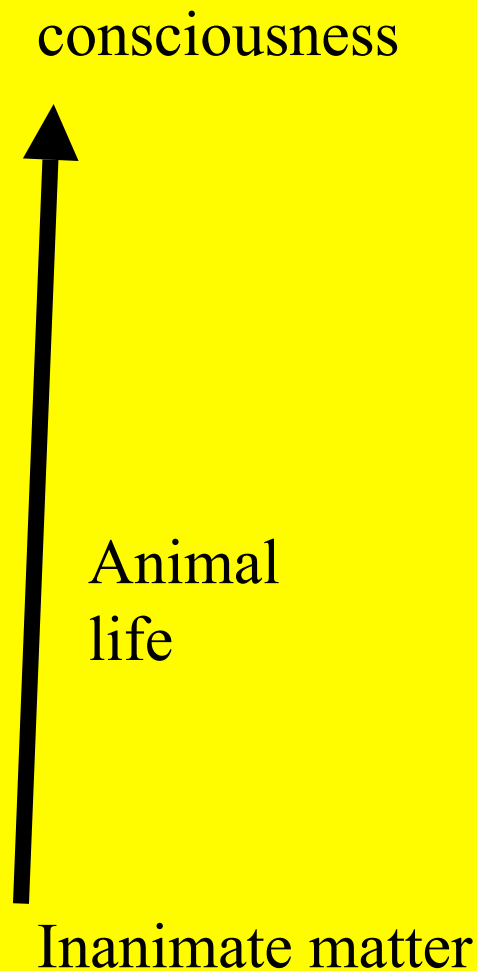




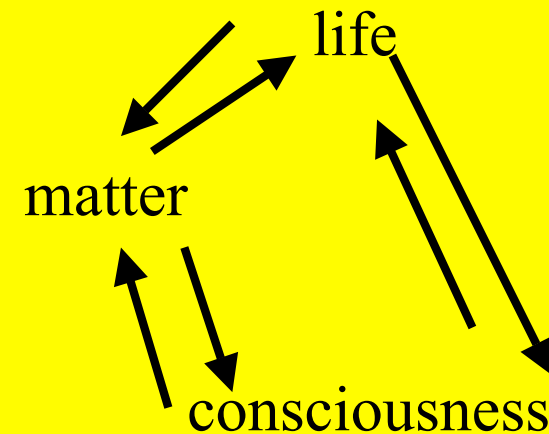
QUESTIONS FOR THE DIALOGUE SCIENCE/BUDDHISM:

The science view

The Buddhist view?



Do we need a
Beginning?



THE LEGACY OF FRANCISCO VARELA:

HARMONISE THE SCIENTIFIC MOLECULAR VIEW
(THERE ARE ONLY MOLECULES AND
THEIR INTERACTIONS)

WITH
THE HUMANISTIC AND SPIRITUAL ASPECTS
OF LIFE
(CONSCIOUSNESS, ETHICS, ART, POETRY,
RELIGIOSITY)