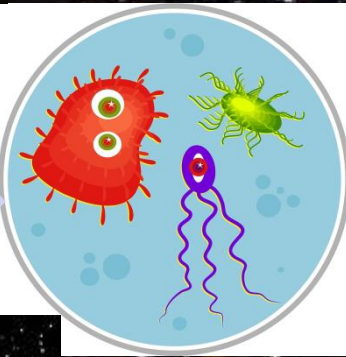
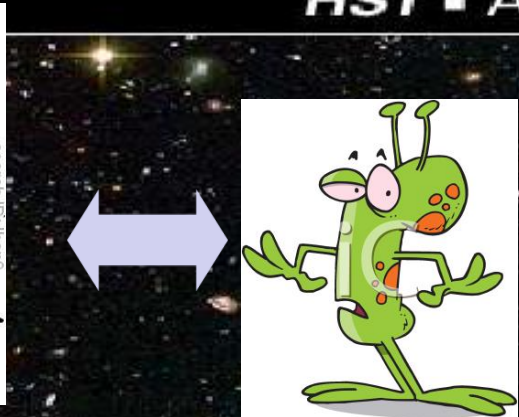
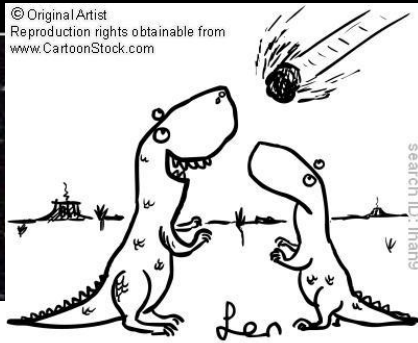


# The life phenomenon and the laws of Physics

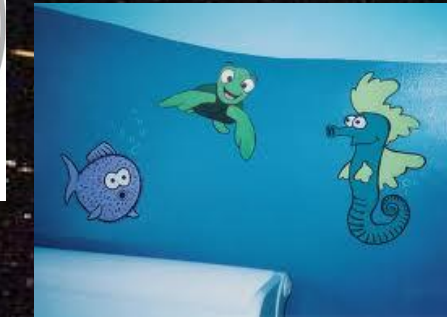


*J.E. Horvath*  
*Astronomia IAG - USP*

© Original Artist  
Reproduction rights obtainable from  
www.CartoonStock.com



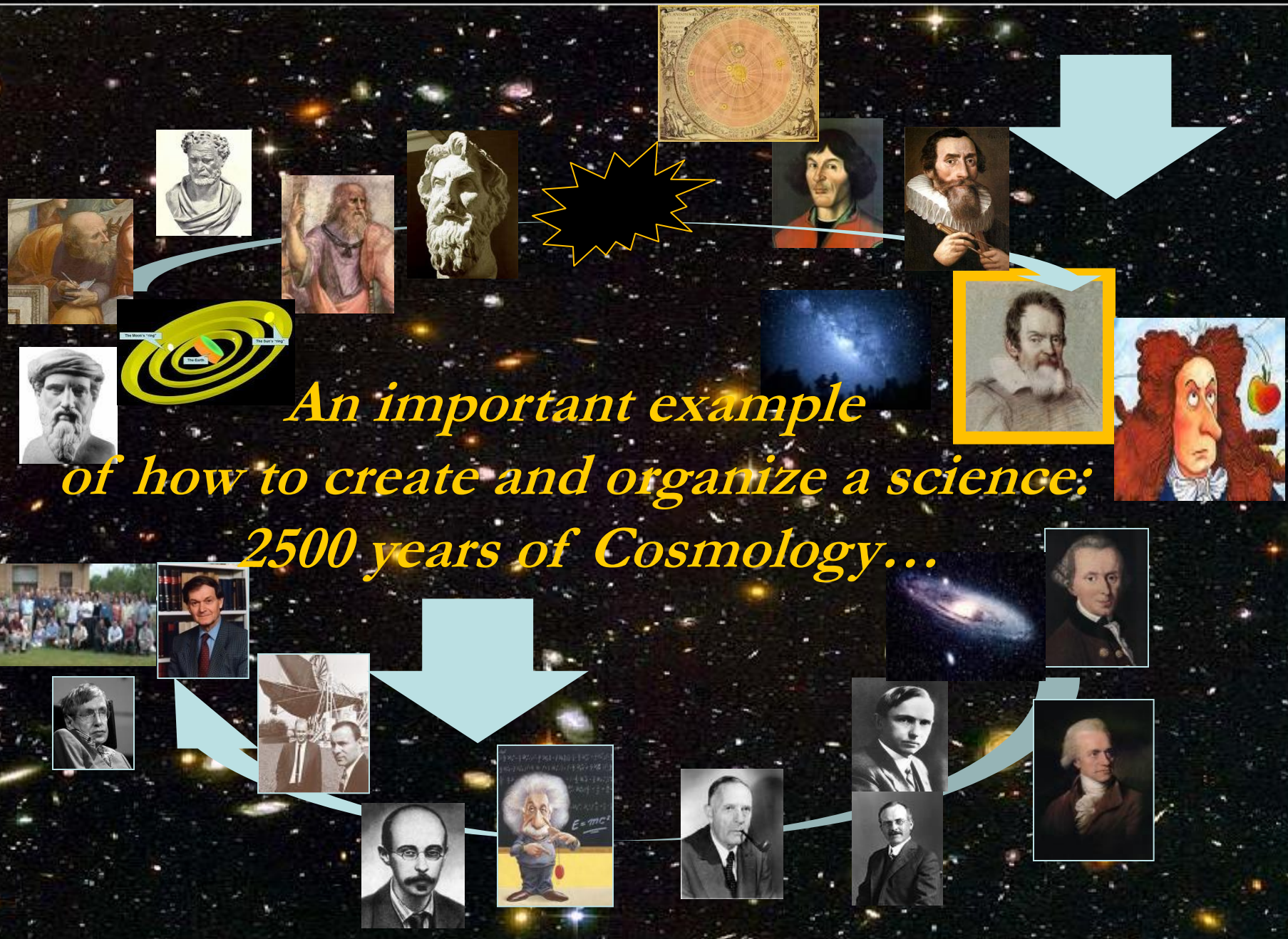
"Ooh, look! A shooting star.  
Make a wish."



HONEST - I HAD  
NO IDEA THEY COULD  
JUMP THAT HIGH!



*Astrobiology is  
all about a gestalt*



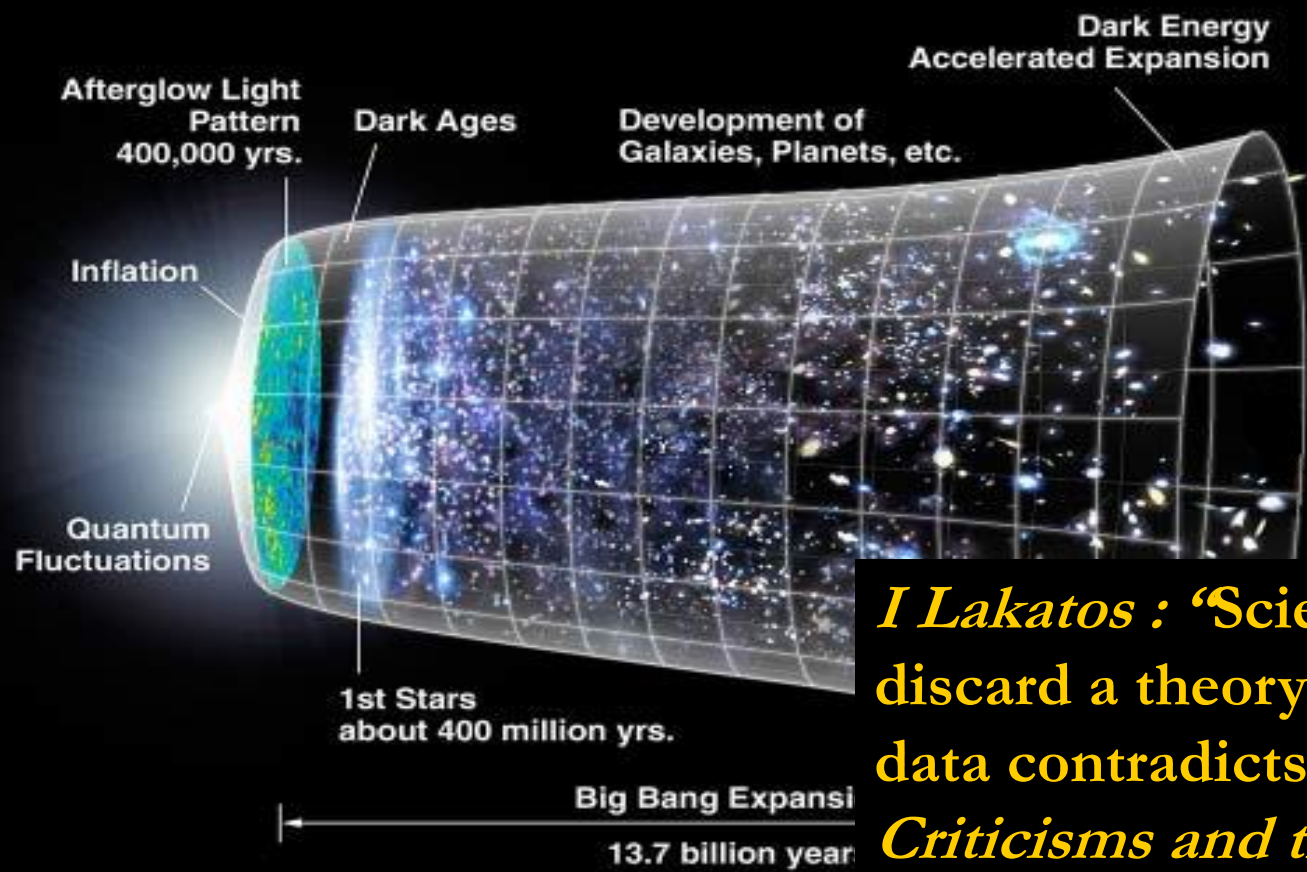
$$R_{\mu\nu} - \frac{1}{2} g_{\mu\nu} R = 8\pi G T_{\mu\nu}$$

$$\frac{\ddot{a}}{a} = -\frac{4\pi G}{3}(\rho + 3P)$$

$$\left(\frac{\dot{a}}{a}\right)^2 = \frac{8\pi G}{3}\rho + \frac{C}{a^2}$$

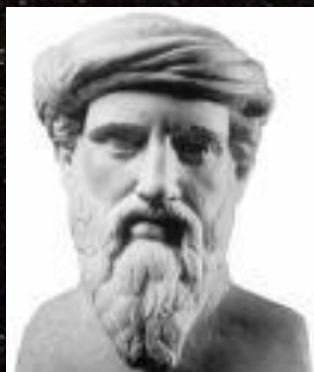
$$\dot{\rho} = -3\frac{\dot{a}}{a}(\rho + P)$$

Physical laws (mathematical form) are part of the *logos* +  $P = \omega\rho$



*I Lakatos* : “Scientists never discard a theory just because data contradicts it”  
*Criticisms and the Growth of Knowledge (1970)*

# Unification vs. Dualities



The world is a mathematical structure



Mind and soul are the same thing, composed of atoms



Complex systems (including biological) come out from a mathematical structure: the algorithm



Plato and the invention of *form*



Mind and matter



Mecanicism (*Deus ex Machina* - robots?) vs. animism (Hume)...



Laws? Fundamental Laws?  
Mere tautologies?

# “Physicalism”, Reductionism and its biological consequences

“Physicalism”: Physics determines all facts  
(there is nothing “supernatural”)



...but it is not so clear if biological processes are **autonomous** from physical processes

They are autonomous :  
Anti- Reductionism

They are not autonomous :  
Reductionism

Epistemic  
(a barrier to  
full knowledge)

Ontological  
(principles)



Opposite to  
**Physicalism !!!**

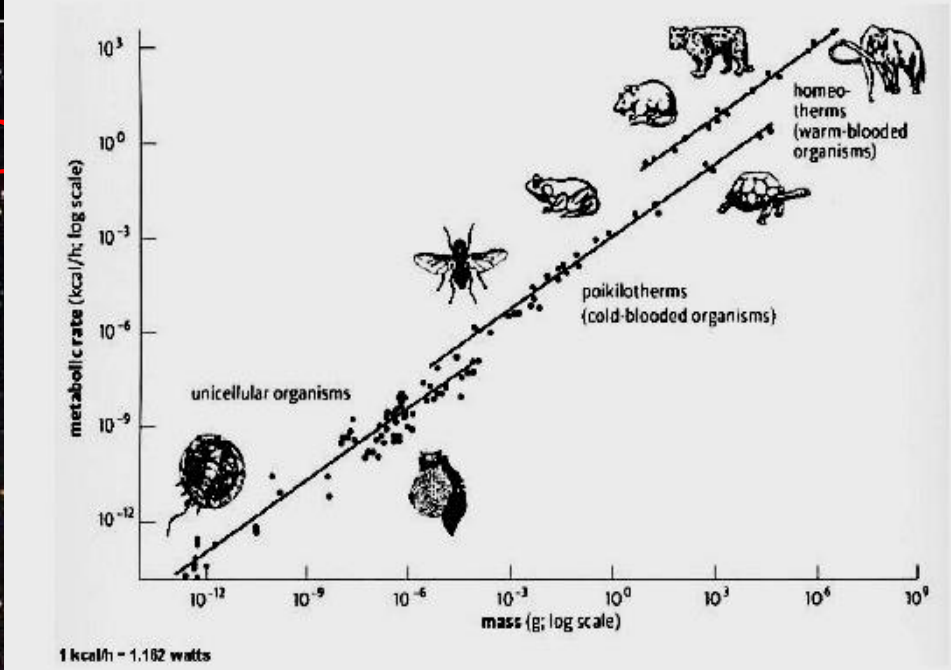
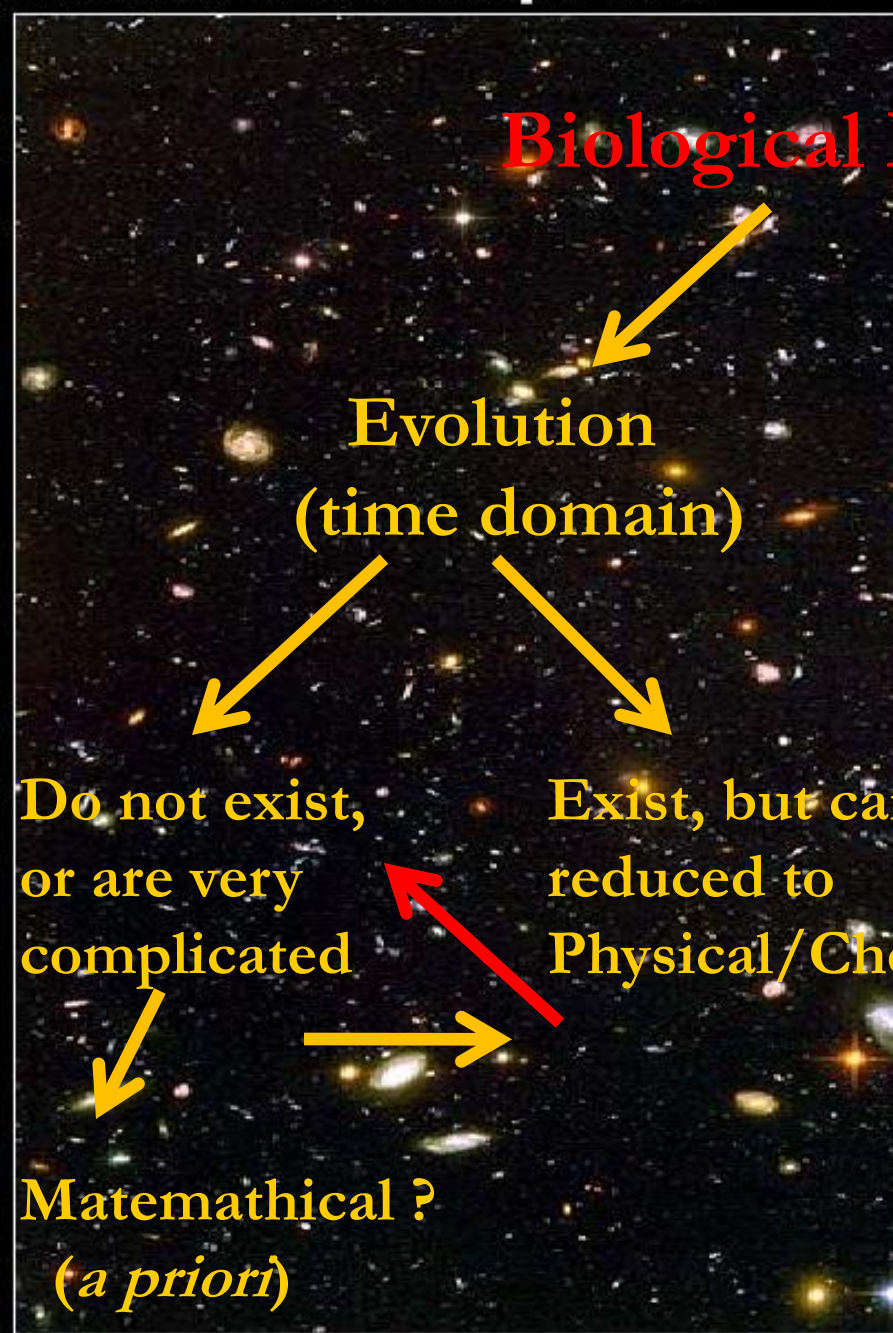
An important example:

the Principle of Natural Selection (PNS)

*If X is more adapted than Y in an environment E,  
Probably there will be a future generation G in which  
X will have more descendants than Y*

- 1) PNS is a **non-derived law** about biological systems **emerging** from physico-chemical processes
- 2) PNS is a **law** about biological systems **derived** from physical/chemical laws (Reductionism)
- 3) PNS is an **autonomous** law about biological systems **in general**, that is, fundamental (anti-Reductionist argument)





**Example: allometries  
(linked to Evolution !)**

**Do not confuse statistical/  
mathematical models  
with truly **fundamental laws**,  
anchored in general  
principles**

# A recent attempt of linking phys/bio: Pross' conjecture

Life can be characterized by a kinetic state of matter in which replication plays a central role. Living beings are the result of a long complexification process, possibly starting with inanimated replicators.

Darwinian evolution should be one emerging corollary

# Key elements of Pross' conjecture

- 1) The essence of life is replication
- 2) Life is associated to the existence of an out-of-equilibrium (thermodynamical) state of the replicator system
- 1) The size of the replicator's space is a measure of their (kinetic) stability
- 2) Evolution consists in transitions of the replicators in the internal space to increase their kinetic stability

However... There is still no clear connection with fundamental principles

Our approach (with O. Martin, UCLV Cuba)

(*Origin of Life and Evolution of Biospheres*, 43, 151, 2013)

- 1) The essence of life is replication
- 2) Life is associated to the existence of a state out of thermodynamic equilibrium near a stationary state of the replicator's system
- 3) The size of the replicator's space is a measure of their (kinetic) stability
- 4) Evolution, driven by the environment (not modelled here) is the new state of replicators in the internal space increasing their kinetic stability towards a higher entropy production (MEPP)

# Pross` conjecture

Original

Our version



Analysis is reduced to the asymptotic behavior (static)

↓

Degeneracy of the models

Possibility of **transient** states (not a maximum)

↓

Breaks the model degeneracy

Potential advantages

Allows the inclusion of environmental fluctuations (cday-night cycles, catastrophic events)

Evolution emerges "naturally"

# More concretely...

$$\frac{d\dot{S}}{dX_i} = 0$$

Maximum Entropy Production Principle  
(MEPP)

$$\frac{dN(X_i, \dots)}{dt} = 0$$

Kinetic stability (metabolism, persistence)

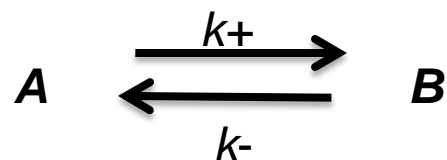


Constrained Lagrangian  
problem?

## Example of how MEPP works

$$\dot{S} = \frac{XJ}{T}$$

Rate of entropy production as a function of generalized thermodynamic forces (X) and fluxes (J)

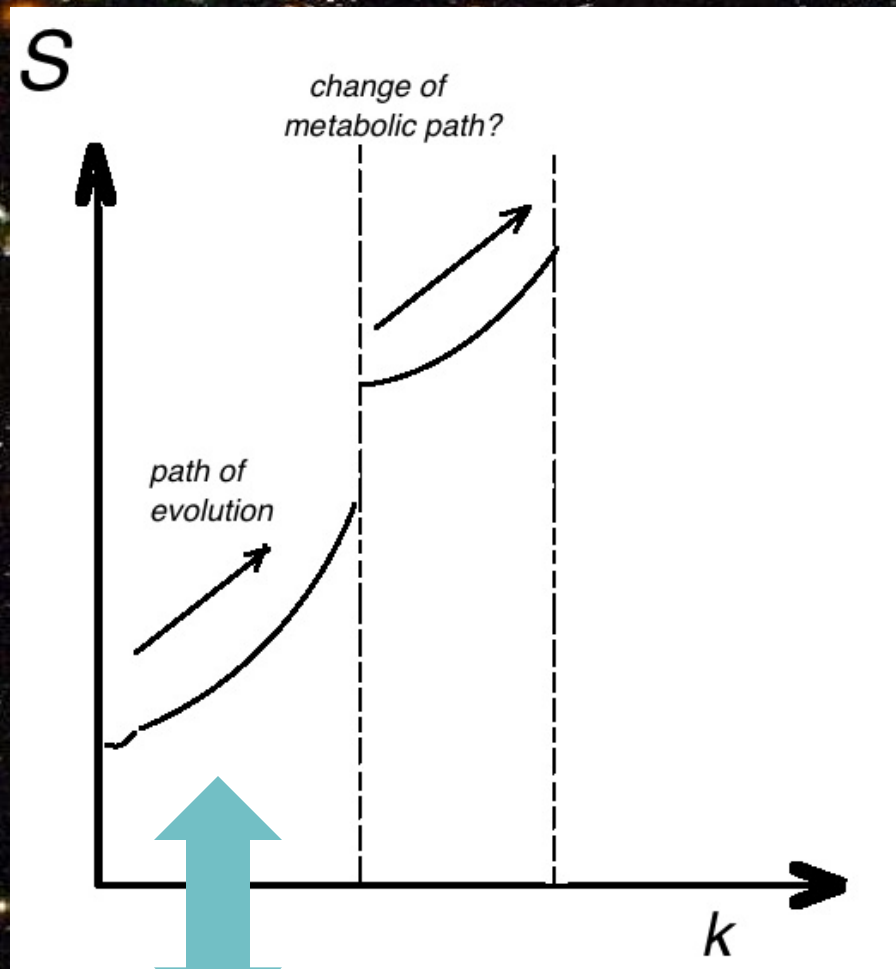


$$\dot{S} = \log \left( \frac{k_{+A}}{k_{-B}} \right) (k_{+A} - k_{-B})$$

In a quasi-reversible process, entropy can be calculated as a function of the kinetic coefficients



Entropy is an homologous function of the kinetic coefficients and **grows** with a scale transformation of the latter



**Given set of constraints  
(i.e. photosynthesis + ambient +...)**



# MEEP as an evolutionary condition

The MEP state of a living being can be considered as an evolutionary advantage of the replicators that form it, continuously subject to external fluctuations



This may be behind the success of several works in which MEPP was applied to biological systems



Has irreversible thermodynamics provided us a “biological law”?

1922 Lotka : total energy flux through the system maximum

1978 Odum : maximum efficient consumption of energy

...

# Press and beyond...

Genetic & environmental  
variation (not modelled)



Kinetic stability *increases*  
(larger constants) = adaptation



Entropy production increase  
(MEPP) towards a maximum



Link of the basic facts of  
Darwinian evolution with  
fundamental physics (MEPP)

$$\frac{d\dot{S}}{dX_i} = 0$$

valid for the  
perfectly adapted  
organism

# Conclusions

- \* Biological laws *can be autonomous*, but nothing precludes that a mathematical form exists. In addition they should have a relationship with physical/chemical fundamentals
- The clearer the connection with fundamental physics
- It is good, and graphs, etc., we are actual



**I'm smiling  
because I don't know  
what the hell is going on**

SOYEZ RÉALISTES  
DEMANDEZ  
L'IMPOSSIBLE

