

Parallels between bio- and hybrid energy storage systems

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Agenda

Bionic approach to the hybrid energy storage solutions

Dimensions

Dimensions of the problem: optimal solutions for electric hybrid energy storage systems

Bio-systems

Bio-systems are ideal examples and paradigm collectors for optimal solutions

Structures

Structures: analogy between bio-systems and storage system

Functions

Functionalities: analogy between the bio systems and hybrid storage systems

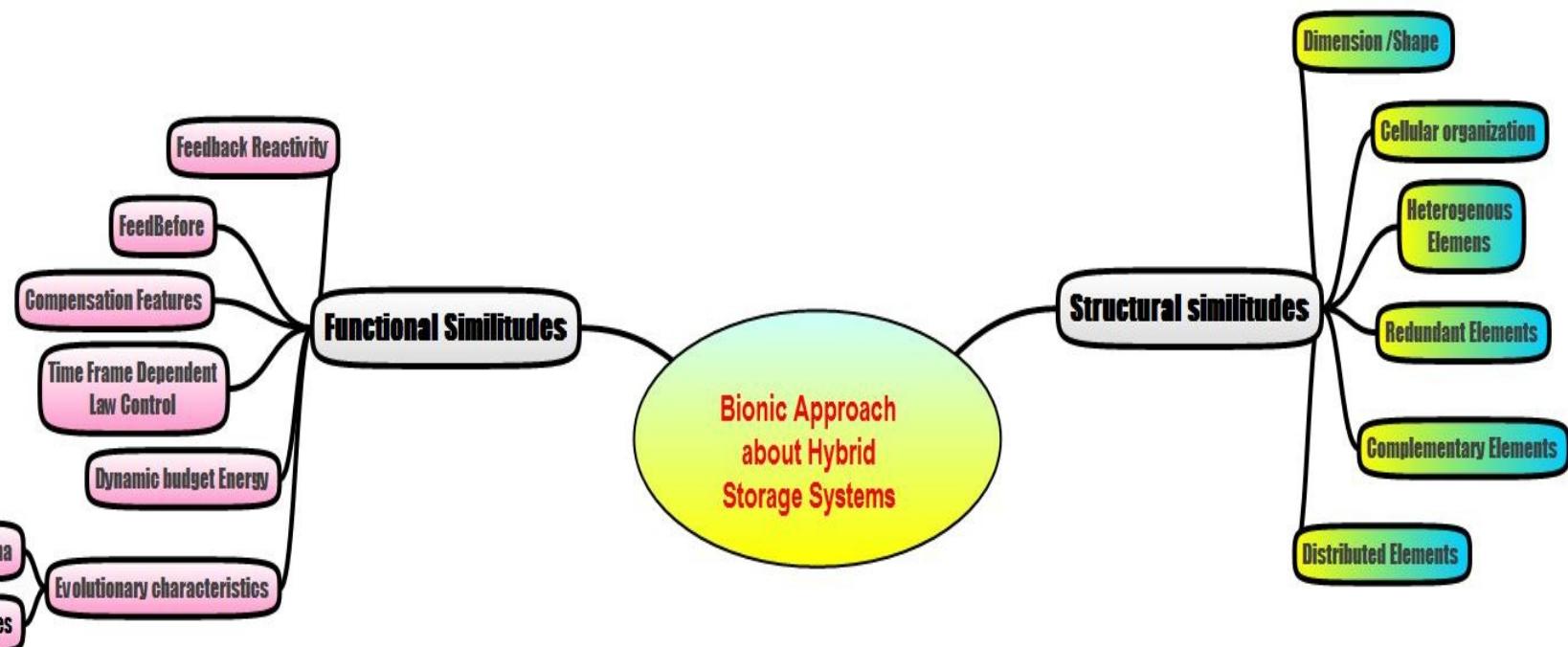
Fusion E&I

Integration of hybrid structures, system features of electric storage systems

Similarities between life systems and hybrid storage systems

STRUCTURAL, FUNCTIONAL AND MATERIAL SIMILARITIES BETWEEN LIVING & TECHNICAL SYSTEMS

- The material aspects are related to the nature of elements and assure that commonly are named hybrid systems



Hybrid storage systems – Dimensions

- Several parameters or features (linear independent) that could be used for system optimization:

Capacities:

Energetic storage capacity

Maximum Power

System Organization:

Cellular

Mono-block

Distributed in space

Time constants:

- Short
- Medium
- Long

Nature of cells:

- Uniform
- Hybrid

Energy & Power

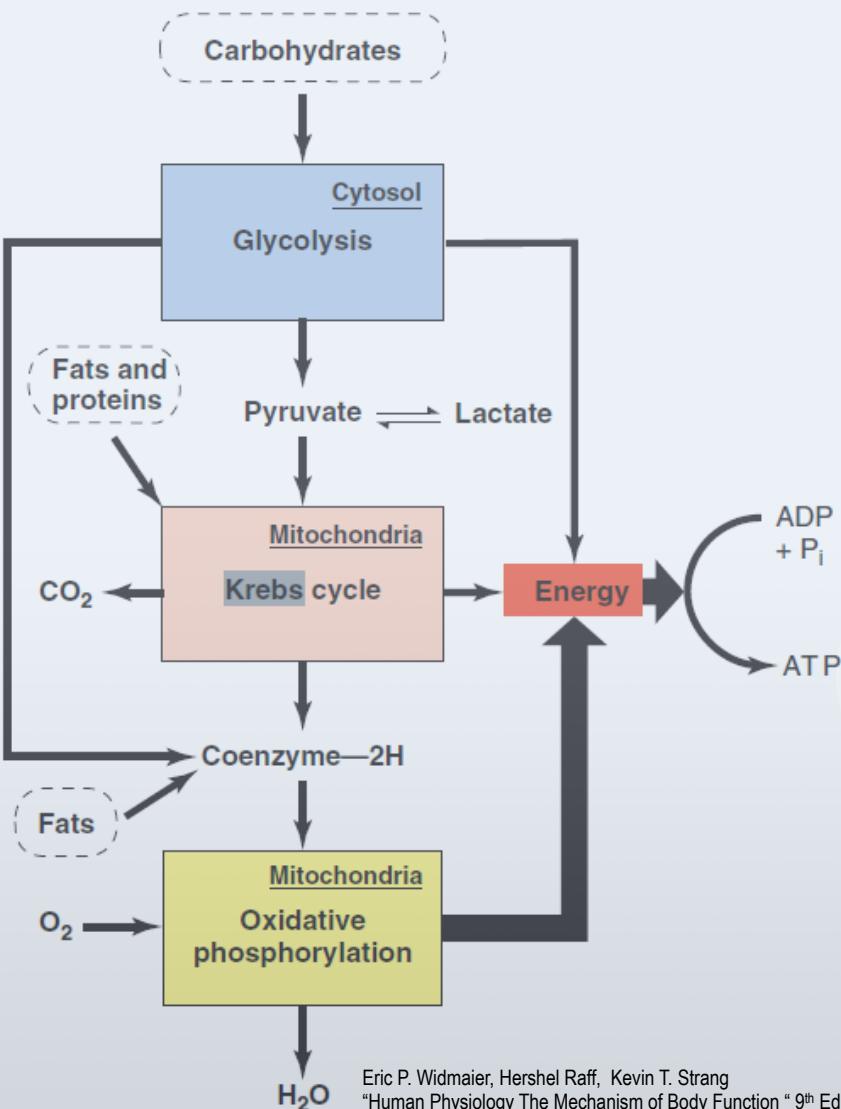
System organization

Time constants



Energy & Power

Bio-systems cellular metabolism “Krebs cycle”



• Glycolysis:

- Could take place in anaerobic (fast) or aerobic conditions (slow).
- Stored reserves:
 - ❖ ATP → is stored in cell (suppose an anaerobic oxidation)
 - ❖ ADP → is stored in cell (suppose an aerobic oxidation)
 - ❖ Glycogen → is stored in liver & muscles (suppose transportation processes using organism's blood circulation)
- Glucose → Glycogen (absorptive state)
- Glycogen → Glucose (post absorptive state)



Time constants of the energetic reserves

Energetic reserves of the living cells



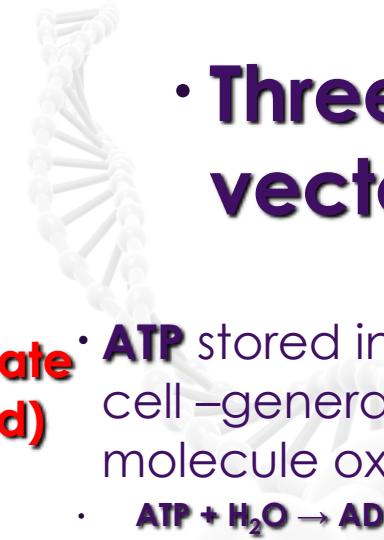
- **ATP acid adenosine -triphosphate (short term energy, locally stored)**



- **ADP acid adenosine -diphosphate (intermediate term energy, locally stored)**



- **Glycogen long term energy reserve, central stored into the liver**



- **Three energetic vectors:**

- **ATP** stored in principal into the cell –generate a 7.3Kcal / link molecule oxidation)

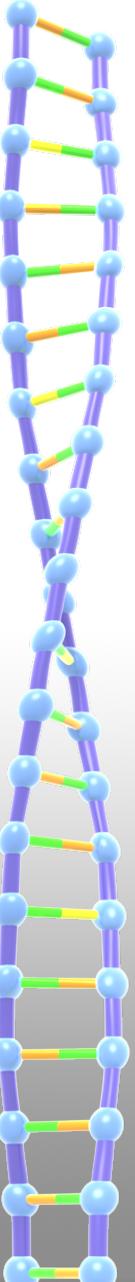


- **ADP** also stored into the cell and could be used as energetic reservoir



- **Glycogen carried by blood in all the body**





Could be considered a cell as an ideal storage system?

Structural features

A bio-cells group represents a distributed energy system

The group of cells represents a **redundant** energetic and also informational source (**compensation** phenomena can be identified in organism)

Functional features

A bio-cell has the ability to auto insulate in report with the whole system, without global damages

A bio-cell assures a “flat time response” for energy & power delivered on demands (very short, short and long term)

Able to auto-reconfigure depending of status of process supplied

Able to auto isolation the damaged / or malfunctioning cells

● Energetic resources in living systems

Involve **distributed** storage of reserves in different cells

Includes two **categories** of reserves: for short & medium term needs

Allow **fast reaction** of the cells at different excitations

Permit a “**flat response**” in time

The local energetic reserves are **finite**

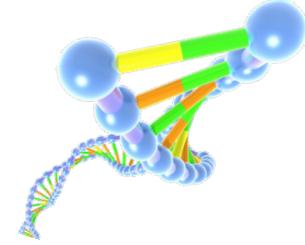
In organism are revealing “**transportation**” processes characteristics for medium and long term needs



A possible hybrid storage system

Starting from structure to arrive at functionality

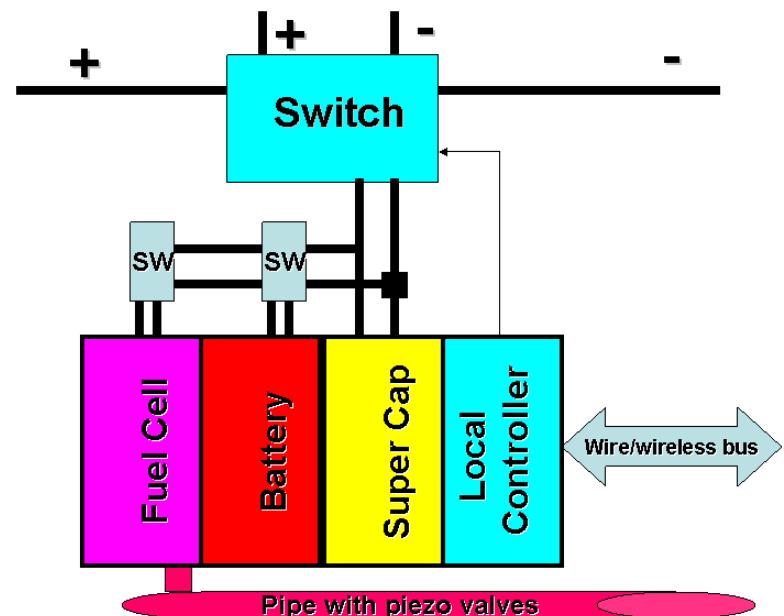
What we gain using a such system?



- A appropriate sizing of every element in order to assures the right balanced ratio between long & short term energetic resources
- An adequate dimensioning of hybrid system in order to satisfy the needs of bidirectional power flow transfer –requested by the specific application –
- A “flat response” in time of the hybrid cell (combined)

? At which level ?

Structural aspect





The redundancy assures the system's reliability

Functional feature

LIVING SYSTEMS

- The assembly of cells having **similar functionality** for a living tissue
- **Integration** of cells means to obtain new features as result of the internal interactions between the cells. Thus, the assembly (organ) will present qualitative/quantitative different feature compared with the sum of component cells
- A **high reliability** is reached as result of highly structurally and functionally redundancy

TECHNICAL SYSTEMS

- Need to be **closely interconnected** each to other. The **preemptive** wiring solutions are in many cases the optimal from energetic efficiency point of view.
- It is mandatory to include on every cell a **minimal set of functions**. Implementation in this case suppose usage of **microcontroller** or **ASIC** circuits. That illustrate the fusion Energy&Information
- Behavior or/and Self Dynamic reconfiguration is an important feature of such systems



Hierarchy & Complementarity

Role of order relationships between system elements

HIERARCHY IS ESSENTIAL FOR OPTIMAL IMPLEMENTATIONS

COMPLEMENTARITY ASSURES AN INCREASING OF ENERGY EFFICIENCY

Structural features

- **Order relationships** are fundamental in order to achieve the optimization of **information flows**.
- In the same sense goal is essential to realize **a proper classification**
- Locally are implements a **static or /and dynamic** grouping of the cells in colonies depending on **their role** and **applications specific**

Functional feature

- **Complementarity** (structural & functional) of electric hybrid storage system contributes at **optimal** and **reliable** implementation of bidirectional power flow transfer with beneficial consequences for increasing of global energy efficiency



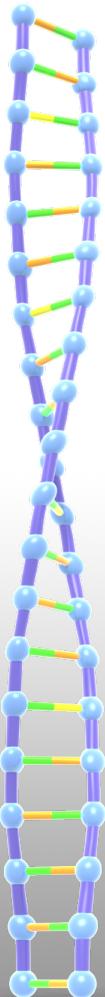
Homeostasis Phenomena

Structural features

Strong homeostasis is the strict constancy of the chemical composition of pools

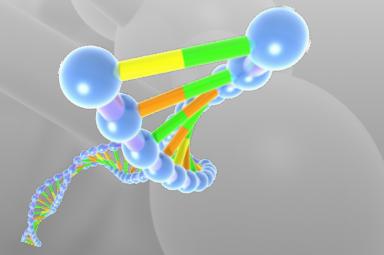
- “Structural homeostasis is the constancy of the shape of the individual during growth”*
- Motivation of research on the theory is to answer the question: *how can we deal with the local coherence of levels of metabolic organization, while avoiding the massive complexity of models with many variables and parameters.**
- Supply – Demands game (strictly dependent of channel capacity)
 - all the applications involve a relatively constancy of needs –see the mechatronic systems /a limited power determined in principal by thermal constraints
- Locality characteristics – the reserves & short time resources are placed in different zones: *short time resources near of acting system* –minimization of power excursion; *long term resources* need to take in consideration “*transportation phenomena*”
- Working into excess prevent the failures – manifestation of redundancy phenomena with two forms: *structural redundancy or dimensional redundancy* & *Functional redundancy*

Where are manifested the homeostasis phenomena?



IN LIVING SYSTEMS

- Structural phenomena such as:
- Chemical equilibrium of organism and their components (cells, tissues, etc.)
- Aqueous concentration and PH
- Dimension of cells tissues and whole body
- Thermal equilibrium



Homeostasis Phenomena

THERMAL HOMEOSTASIS

Functional feature

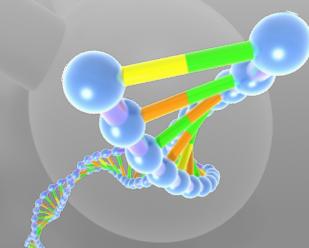
Means a relatively stability of inner behavior in comparison with the significant variation of environmental parameters based on feedback, feed before and context dependent control law that are hierarchical distributed

The functionality of whole system is sustained by his components and their inner, self, static or dynamic organization

As result of this characteristic the highly dynamics of the system response is realized

Hybridization as reflection of highly specialization of system's components generate reliability, resilience and availability for whole system

Redundancy versus feed back loop intricate are two conditions for preserving stability, resiliency and availability.



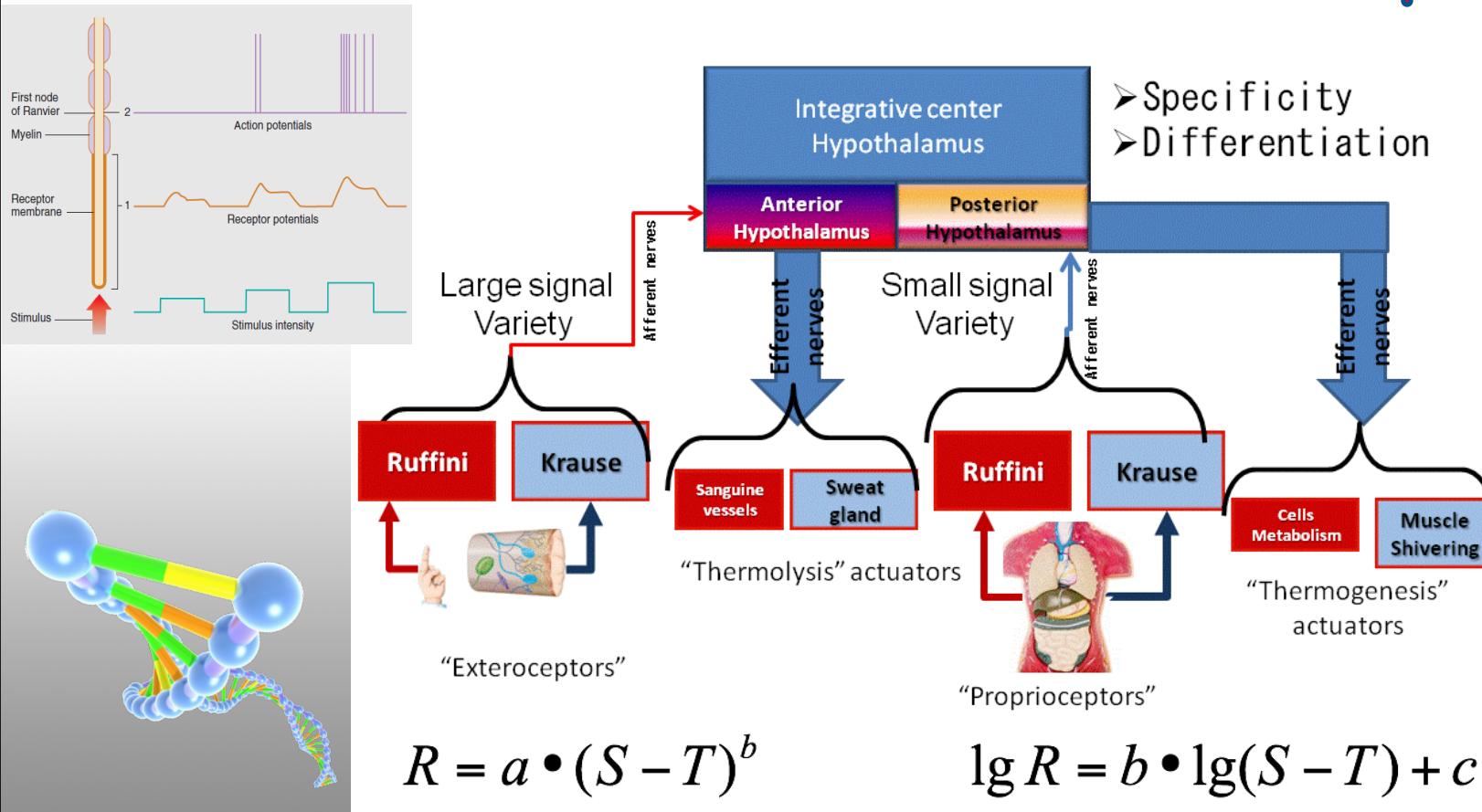
Example coming from live world

Thermal regulation system (thermal homeostasis)

HOMEOSTASIS : A FRAMEWORK FOR HUMAN PHYSIOLOGY

CONTROL PROCESSES ASSURING THE RELATIVELY ,CONSTANT OF INTERNAL BODY BEHAVIOR BY MAINTAINING CONSTANT THE BODY TEMPERATURE

Functional feature

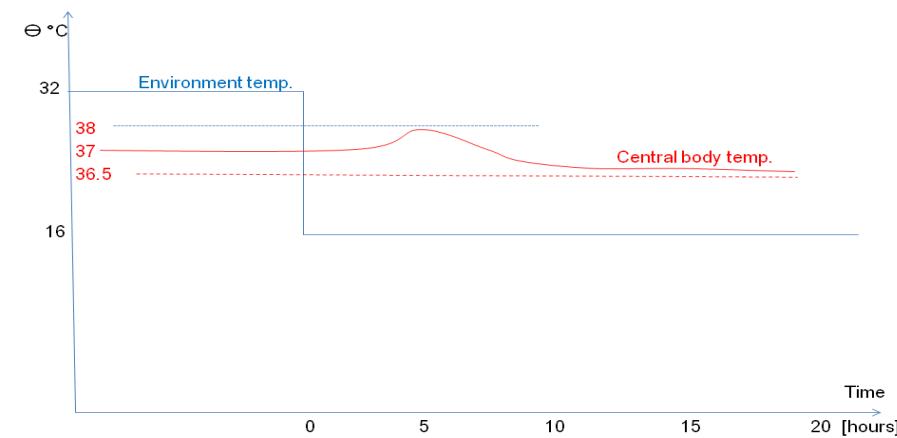
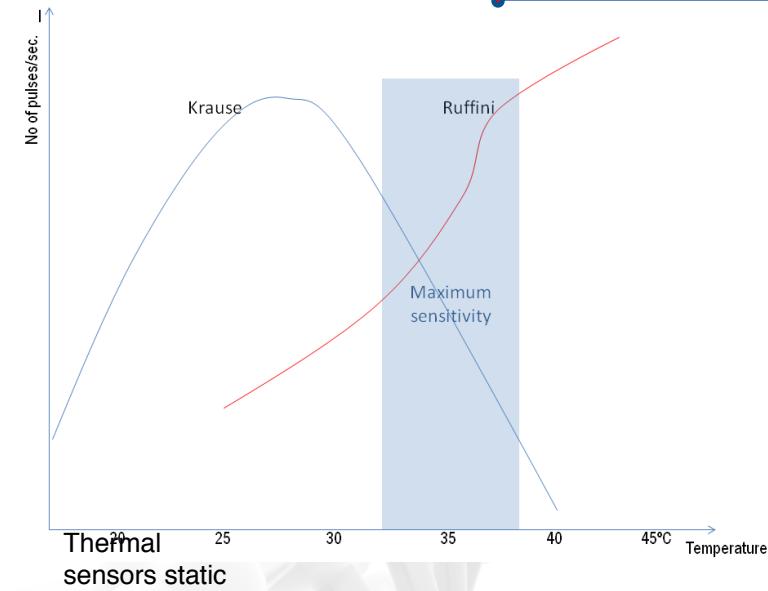


R=response
S=Stimulus
T=Threshold
b = exponent factor

Performances in thermal regulation

PARADIGMS RESULTED FROM THERMAL HOMEOSTASIS ANALYSIS

- Optimal systems should includes differential high sensitivity sensors
- The complementarity and structural redundancy of the thermal regulation system brought an exceptional quality of temperature regulation
- The different time constants of sensors and also actuators brought a new level of quality of temperature regulation



Exceptional regulation characteristics

Lessons learned from bio-systems

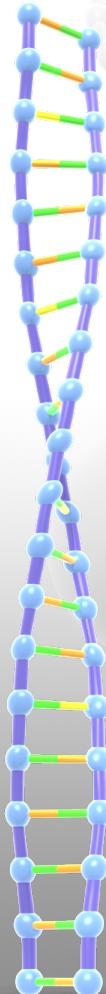
From thermal homeostasis to optimal control

FROM LIVING SYSTEM

- Specificity of sensors (warm/cold) having complementary static characteristics
- Different informational communication channels in accordance with the variety of the signals transferred
- Specific actuators for thermolysis versus thermogenesis
- Specific processing units view as process computers (hypothalamus anterior versus posterior)
- Logarithmic coding of signals transferred with a high noises immunity

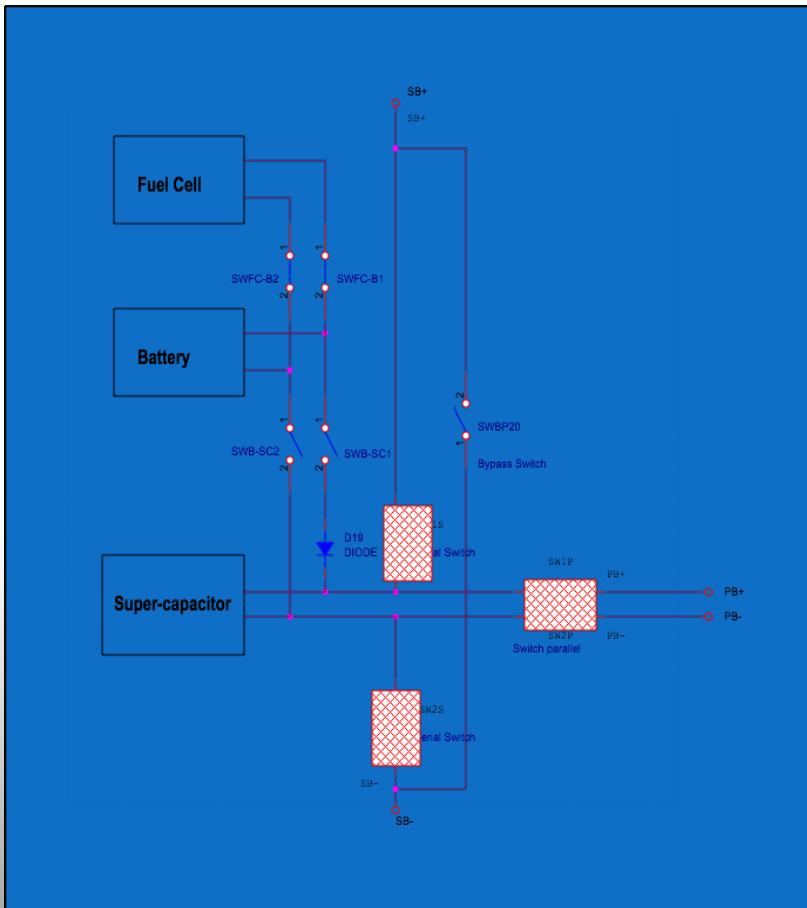
BY TECHNICAL SYSTEM

- Endowing the hybrid storage cell with specific sensors that is suitable to work independently
- It is suitable to build up un architecture with redundant elements
- It is better to implement for every cell his specific controller able to it optimal integrate in cell's colony
- Frequency signal coding assure a higher noise immunity and create the premises for an accurate control of the electric hybrid storage system



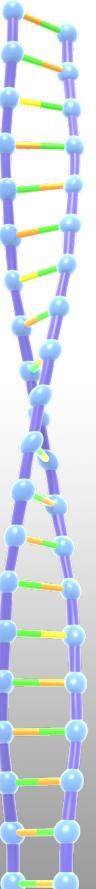
Electric Power Cell (EPC)

A possible example



FUNCTIONING PHASES OF A EPC

1. Insulation of cell that must be “revitalized”
2. Pumping of charge from battery into the super-capacitor at a limit initial established
3. Disconnecting of super-capacitor from battery
4. Connecting the CEC, respectively the super-capacitor at the colony network
5. Connecting the battery at fuel cell in order to charge again the battery at maximum level in order to be able to assure the next charging of super-capacitor
6. Control the supplying process at the fuel cell level by controlling the methanol access into the cell, and preserving by control the variation of temperature in initial settled range.



Could be now implemented such systems?

SEVERAL REMARKS ABOUT POSSIBILITIES TO IMPLEMENT THE FUTURE EV

- Stacked super-capacitors (SSC) are ready to use!
Why SSC? High voltage systems without SSC suppose important difficulties in implementation and integration
- Stacked super-capacitors are ready to be used
- Fuel cell at low temperature exist now DMFC represents an example
- We are able to integrate all of them in one hybrid component?

Heterogeneity

Assures the stability & reliability of the hybrid storage systems

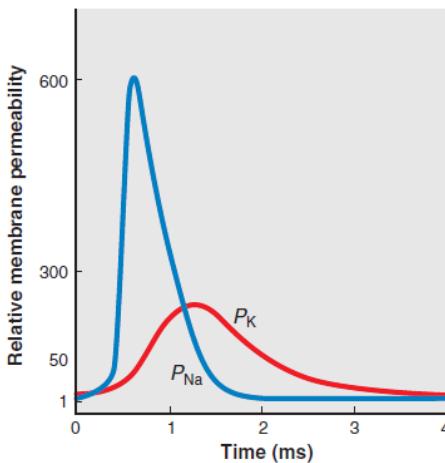
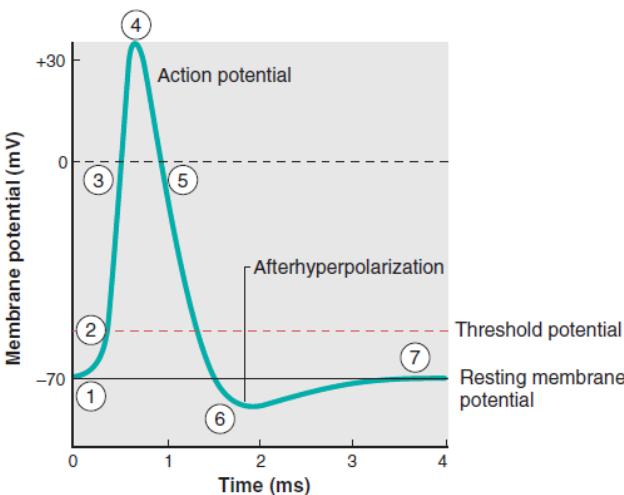
- See *adrenalines versus noradrenalin's* complementary chemical factors having their own reaction time constants – represents the key factor in transmission of information at synapses level - temporality of life laws
VERSUS
- Dynamicity of power conversion at storage / actuator level – see supercaps (SC) & DC acting drives
- Heterogeneity of energy sources means in the same time **increased reliability and availability of system by lowering of fault probability => increasing of structural complexity generate more stability and reliability!**



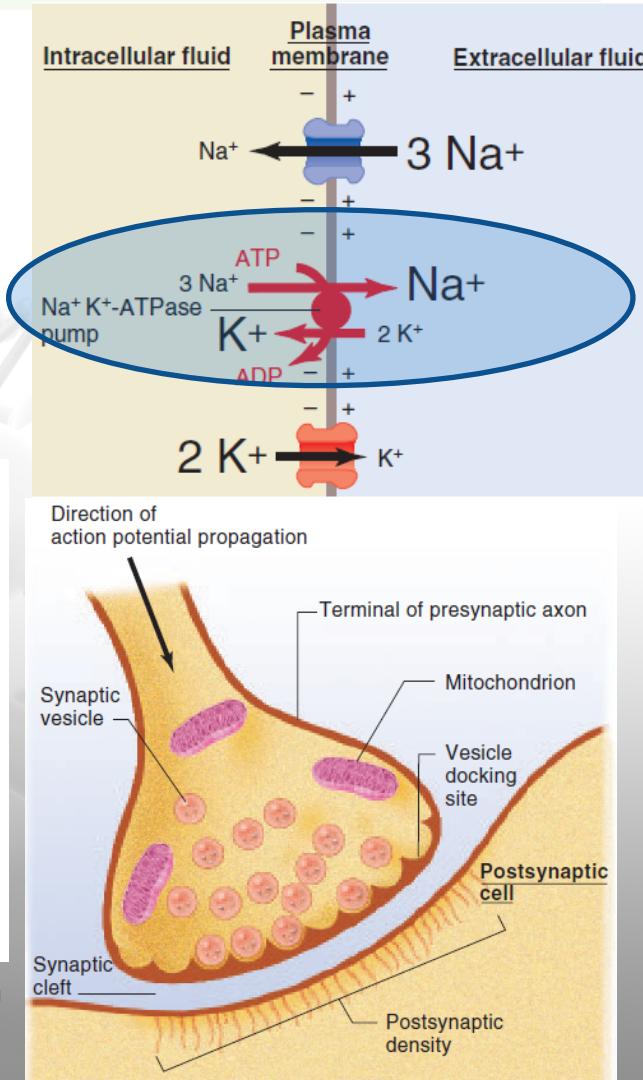
Example: Neural synapses

HETEROGENEITY AID AT STABILITY AND ALSO NOISE IMMUNITY OF SIGNAL TRANSMISSION ALONG NEURAL COMMUNICATION CHANNELS

- Spatio-temporal integration of the signals
- Finite quanta of neural-mediator and a threshold potential assures the increasing of noise immunity for excitation propagation along neural communication channel



Eric P. Widmaier, Hershel Raff, Kevin T. Strang
"Human Physiology The Mechanism of Body Function" 9th Ed



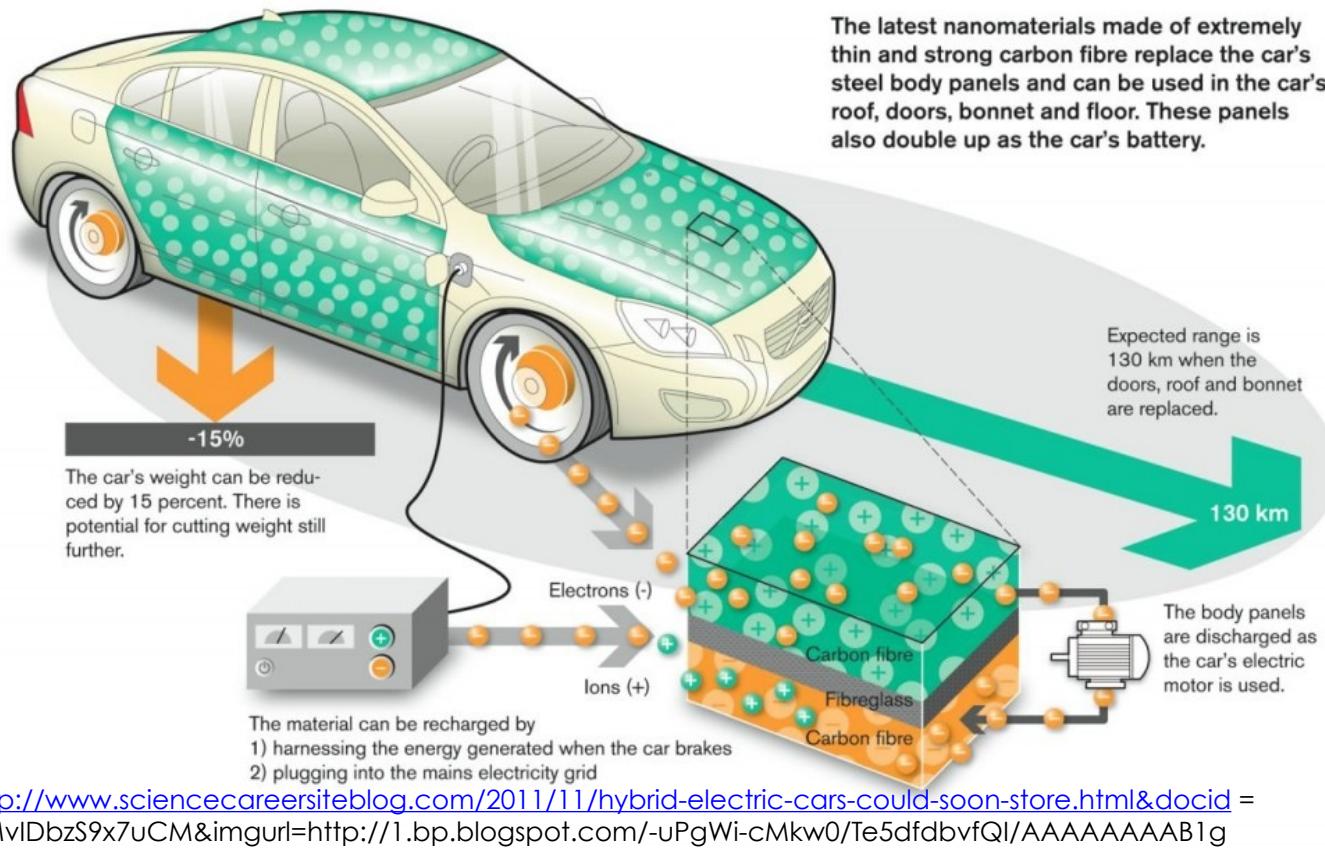


Example of integration for electric storage system in a car

STRUCTURAL & FUNCTIONAL INTEGRATION OF STORAGE SYSTEM ON A CAR

Structural features

The car's body panels serve as a battery



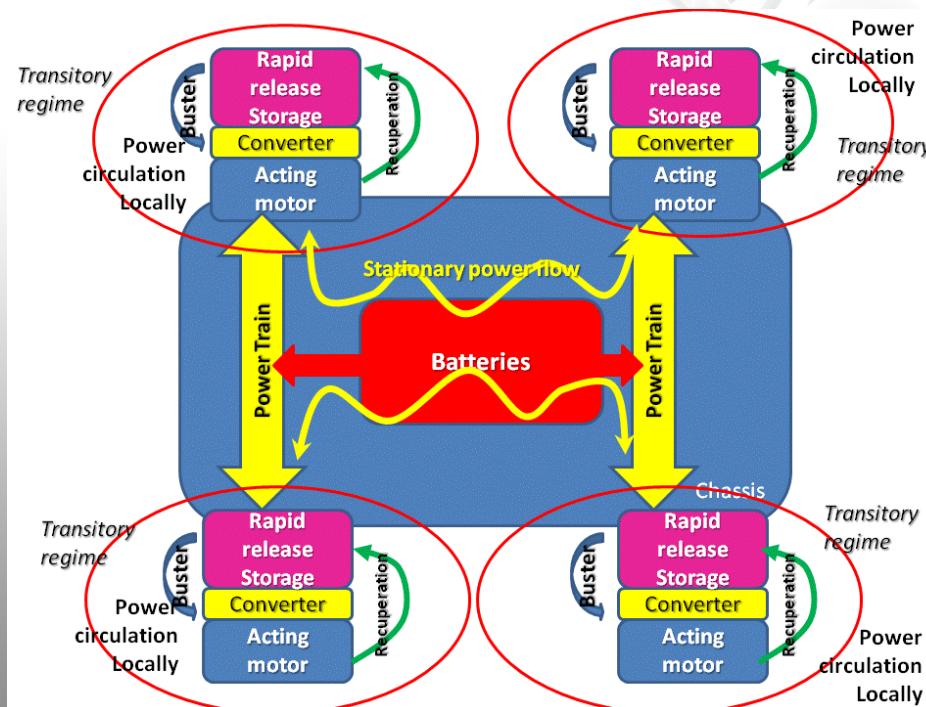
- Weight reduction 15%
- Reduction of power flow excursion between batteries & acting motors
- Better balancing of the weight between axis of the car

What means to apply several paradigms results of bionic vision?

POWER DISTRIBUTION ON A CAR TRANSITORY & STATIONARY POWER FLOWS

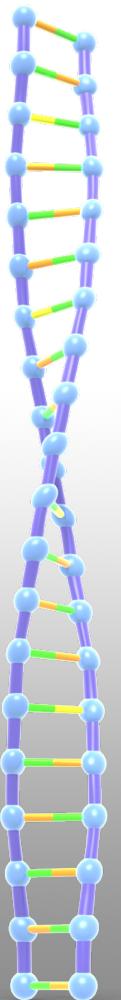
- Structured design with hierarchical elements
- Optimization by minimizing the power flows excursions between batteries & rapid release storage elements and the acting motors
- Better balancing of the weight between axis of the car
- Modular design (cellular)

Structural features

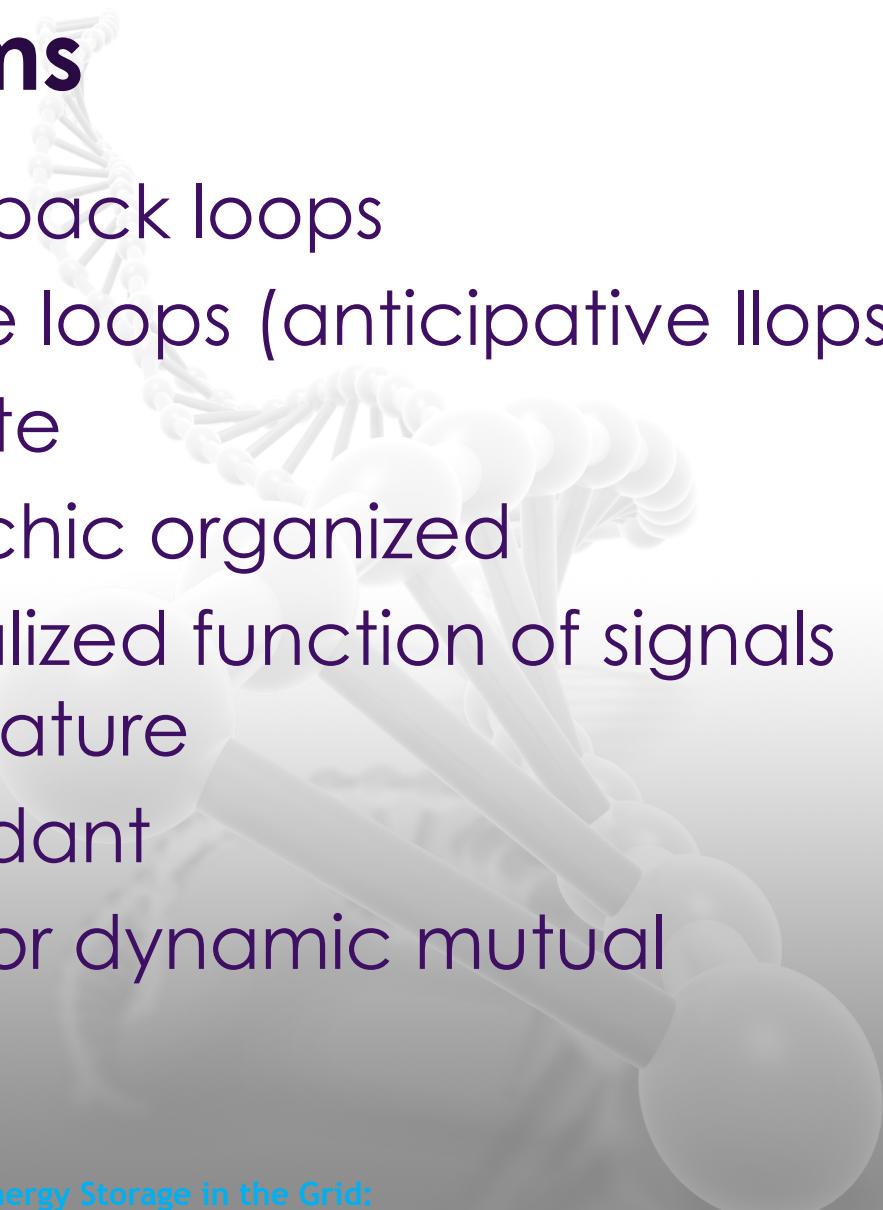




Bio-systems are hyper complex cybernetic systems



- Includes many feedback loops
- Includes feed before loops (anticipative loops)
- The loops are intricate
- The loops are hierarchic organized
- The loops are specialized function of signals variety and signals nature
- The loops are redundant
- The loops are static or dynamic mutual dependent



A stationary example that illustrate the application of bionic paradigms

MODERN POWER NETWORKS INCLUDING RENEWABLE AND DISTRIBUTED POWER SOURCES AND CONSUMERS

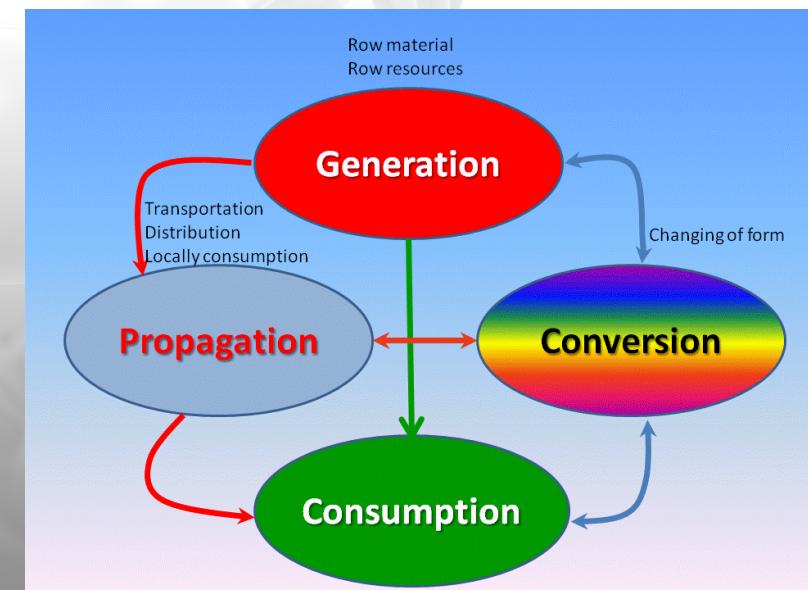


From www.e-energy.de view on 02.03.2012

Several remarks

POWER DISTRIBUTION NETWORKS – FEEDBACK LOOPS INSIDE THE SYSTEM -

- Domotic (home appliances) loops at residential or administrative buildings
- Distribution grids
- Transportation grids
- V2I loop and emerging area (assures the interconnection between the stationary and mobile world)
- Specificity of generation: coal production, hydro-electric, atomic, wind, solar, micro-generation
- Dimension of generators (big generators) versus Locality (small, distributed generators)
 - Degree of variety (global versus local) generation & consumption
 - Ontology of energetic processes





Aspects that will request an important research effort in the future

- **Definition of the optimal Granularity** of Combined Energy Source (CES) and of CEC, adequate at application specifics must be analyzed. In transportation systems the programs that will run on CEC controller will be different comparing with the case of Distribution Energy Management System (DEMS) or active filter systems.
- Development of a designing flow for dimensioning of the hybrid storage systems elements function of application requirements
- Study of role and optimized **redundancy** structures adapted for hybrid electric storage systems (e.g. CEC elements) and its integration into colonies
- Developing of adequate **strategies for insulate** the individual CEC and **replacing algorithms** will represent “must” for the future researches.
- Developing of optimal strategies for controlling of hybrid storage systems in order to improve the system (global) energy efficiency

Aspects that will request an important research effort in the future

-continuation -

- Development of an adequate hierarchical & distributed system able to control under real time constraints the individual storage cells and also the hybrid electric storage devices translating in practice the desiderate of fusion between **Energy&Information**
- The controllers of CEC colony must formed a **cluster** for computation and control of Combined Energy Source (CES)
- Seems to be natural to search the future solutions in the domain of **informational networks**
- It is natural to think the implementation of controlling system like an **IP solution** the controlling system for the CEC included into the colony
- It is preferable to use **wireless communication** channels for the transfer of information between CEC
- The **intelligent agents** seems to be an appropriate solution for the control of whole CES



Challenging aspects that need to pay a significant attention in research

- Technological aspects related to hardware implementation of CEC elements
- Developing of a specific parallel architecture for the controlling system of CES
- Theoretical substantiation of CEC
- Developing of a specific parallel processing control of CES
- Applications and deployment of research results



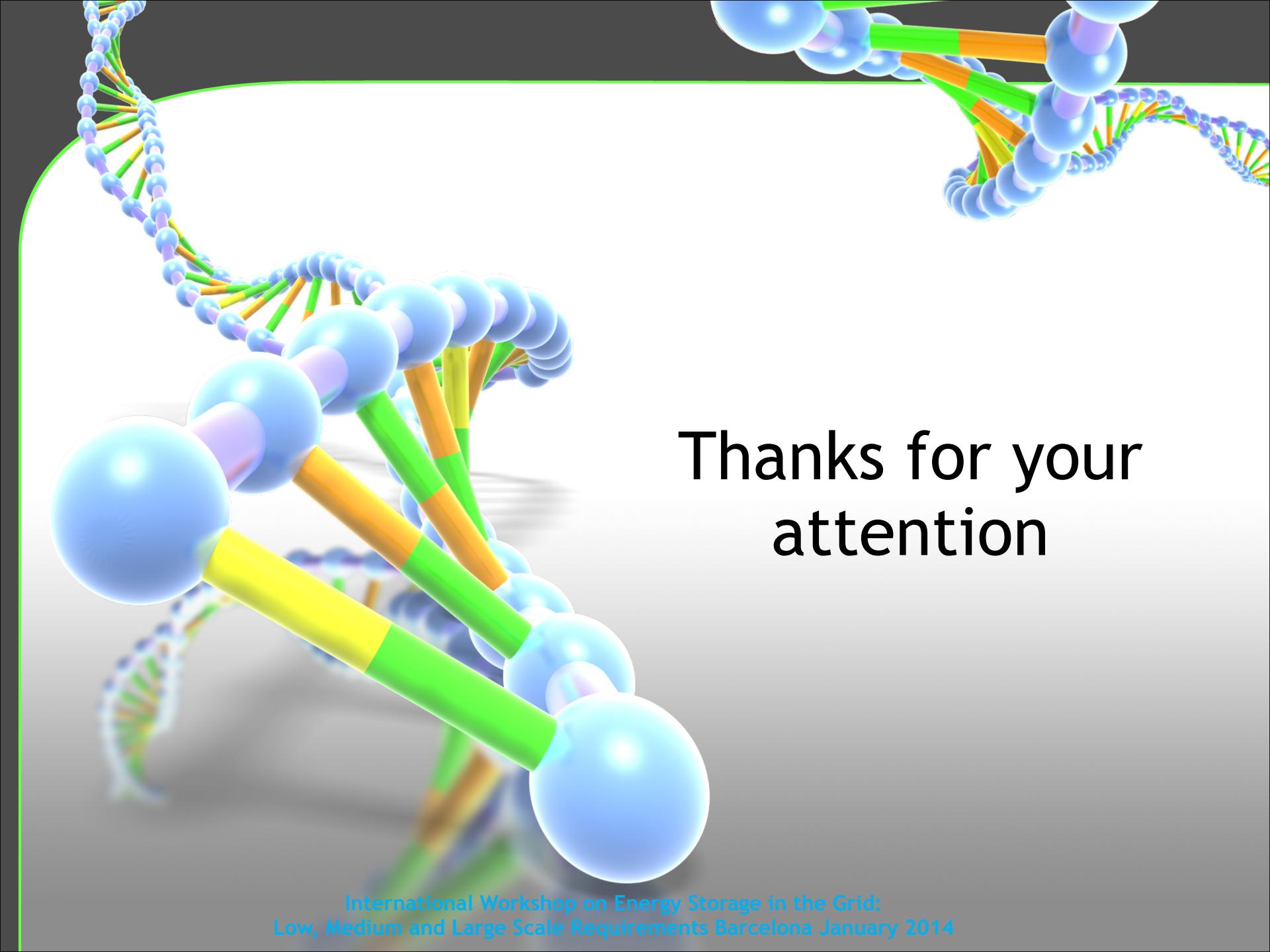
Conclusions?!

EVERY PROBLEM NEED HIS SPECIFIC (OWN) SOLUTIONS

- From conceptual thinking to detailed, technical design and implementation
- Interdisciplinary is a must in our time !
- Inspiration: look at your self!
- Innovation: please have the courage to say and to act!
- Propagation: please spoke the same language (in techniques the standard –if exists, if not invent its!)
- Don't worry if peoples say is stupid! This is an argument to verify again your assertion – the world is intrinsically complementary!
- Main functionality consist in dialog and debating
- Essential ethics, honesty
- Dreaming but permanent staying with your foots on earth!
- Believe but verify !.....

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Thanks for your
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