



Uniwersytet
Kardynała Stefana Wyszyńskiego
w Warszawie

Towards a Contemporary Ontology

The New Dual Paradigm in Natural Sciences: Part I

Module 6: The DDF Principle of QFT and its Cosmological Relevance

Course WI-FI-BASTI1

2014/15

Introduction

Module 6: “The DDF Principle of QFT, its Cosmological Relevance and Its Ontological Interpretation”

Course modules

Modules	Topic	Suggested Readings
SECTION ONE		
0.	<i>Introduction and Course Overview</i>	
1.	The Birth of Modern Science	Refs.: 1, chs. 0, 1, 2.
2.	The Question of Truth in Modern Science	Refs.: 1, chs. 3, 4.
SECTION TWO		
3.	The Information Theoretic Interpretation of QM	Refs.: 4-10.
4.	QFT interpretation as ‘Second Quantization’ and the Physics of the Condensed Matter	Refs.: 11, pp. vi-xii, 1-35, 137-178; 12; 13.
SECTION THREE		
5.	The (Co)Algebraic Interpretation of QFT as q-deformed Hopf Algebra / Coalgebra	Refs.: 11, pp. 131-185; 14.
6.	The DDF Principle of QFT, its Cosmological Relevance and Its Ontological Interpretation	Refs.: 14-19; 1, ch. 5.
SECTION FOUR		
7.	Universal Coalgebra and the Interpretation of QFT Systems as STS	Refs.: 16; 20
8.	<i>Conclusions</i>	

Bibliography

Bibliography of the Module 6

Bibliography

- **Main References:**

- G. BASTI, *Philosophy of Nature and of Science, vol. 1: The foundations*, transl. by Philip Larrey, Rome 2012 (for student use only), ch. 2 [[attached](#)]
- G. BASTI, *QFT: An Evolutionary Interpretation Of Nature From Cosmology To Neuroscience* [[Lecture Notes:attached](#)].

- **Other References:**

1. M. BLASONE, P. JIZBA, G. VITIELLO, «Preface», in: *Quantum field theory and its macroscopic manifestations. Boson condensations, ordered patterns and topological defects* , Imperial College Press , London, 2011, pp. vii-xii.
2. G. VITIELLO, «Links. Relating different physical systems through the common QFT algebraic structure», *Lecture Notes in Physics*, 718 (2007), 165-205 [[attached](#)].

Bibliography II

3. E. DEL GIUDICE & G. VITIELLO, «The role of the electromagnetic field in the formation of domains in the process of symmetry breaking phase transitions», *Phys. Rev.*, A74 (2006), 022105. [\[attached\]](#)
4. Del Giudice, E., Pulselli, R., & Tiezzi, E. (2009). Thermodynamics of irreversible processes and quantum field theory: an interplay for understanding of ecosystem dynamics. *Ecological Modelling*, 220, 1874-1879 [\[attached\]](#).

Module 6

“The DDF Principle of QFT, its Cosmological Relevance and Its Ontological Interpretation”

QV in QFT

- The notion of quantum vacuum QV is fundamental in QFT. This notion is the only possible explanation at the fundamental microscopic level, of the *third principle of thermodynamics* (“The entropy of a system approaches a constant value as the temperature approaches zero”).
- Indeed, the Nobel Laureate Walter Nernst, first discovered that for a given mole of matter (namely an ensemble of an Avogadro number of atoms or molecules), for temperatures close to the absolute 0, T_0 , the variation of entropy ΔS would become infinite (by dividing per 0). Namely:

$$\Delta S = \int_{T_0}^T \frac{\partial Q}{T} = \int_{T_0}^T C \frac{dT}{T} = C \ln \frac{T}{T_0}$$

Where Q is the heat transfer to the system, and C is the molar heat capacity, i.e., the total energy to be supplied to a mole for increasing its temperature by 1°C .

QV, and the change of paradigm as to CM...

- Nernst demonstrated that for avoiding this catastrophe we have to suppose that **C is not constant at all, but vanishes**, in the limit $T \rightarrow 0$, **so to make ΔS finite**, as it has to be. This means however, that near the absolute $0^\circ K$, there is a mismatch between the variation of the body content of energy, and the supply of energy from the outside.
- We can avoid this paradox, only by supposing that **such a mysterious inner supplier of energy is the vacuum**. This implies that the absolute $0^\circ K$ ($-273^\circ C$) is unreachable. In other terms, there is an unavoidable fluctuation of the matter fields, at whichever level of matter organization.
- The ontological conclusion for fundamental physics is that **we cannot any longer conceive physical bodies as *isolated***, as the inertia principle of Newtonian mechanics requires. The QV – as opposed to the mechanical vacuum of classical mechanics (CM) – plays thus the role of “inner reservoir of energy” of whichever physical system that the Third Principle of Thermodynamics necessarily requires.

The QV in QFT as to QM

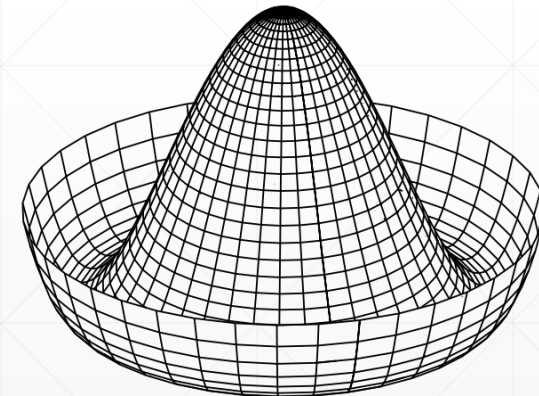
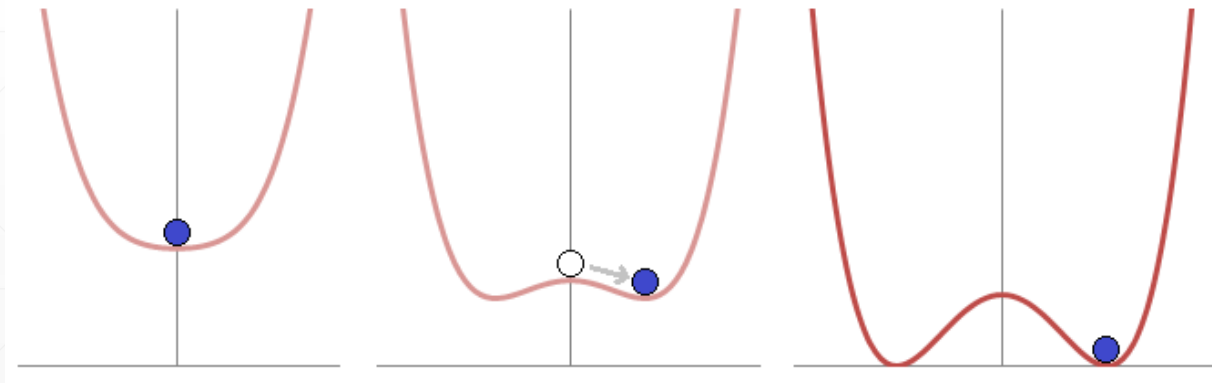
- Moreover, as to QM:
 1. The QV at the fundamental level cannot be interpreted as a Fock state with no occupation number, and hence with a temperature $\approx 0^\circ K$ like in QM and in OQFT. The QV in cosmology must be conceived with a finite temperature $> 0^\circ K$, even though with all energy bounded (no free energy), as required in thermodynamics.
 2. The fluctuating nature of QV fields implies the necessity of an infinite volume for allowing the passage from **discrete to continuous representations** →
 3. → From coherent states algebraically represented as structures defined on points (equivalently, a Schroedinger wave function within a finite «energy box») of QM → to potentially infinite number of **field phase coherences in the infinite volume of QV**, corresponding to **the infinitely many UIR's of Haag's theorem in QFT** – generally considered as an oddity in OQFT because «*this theory has proved astonishingly successful in application to experimental results*» (P. Teller).

To sum up...

- «The vacuum becomes **a bridge that connects all objects among them**. No isolated body can exist, and the fundamental physical actor is no longer the atom, but the field, namely the atom space distributions variable with time. Atoms become the “quanta” of this matter field, in the same way as the photons are the quanta of the electromagnetic field» (Del Giudice, Pulselli, & Tiezzi, 2009, p. 1876).
- For this discovery, eliminating once forever the notion of the “inert isolated bodies” of Newtonian mechanics, **Walter Nernst is a chemist who is one of the founders of the modern quantum physics**.
- In this sense, “QFT can be recognized **as an *intrinsically thermal quantum theory***” Of course, because of the intrinsic character of the thermal bath, the whole QFT system can recover the classical Hamiltonian character, because of the necessity of anyway satisfying the energy balance condition of each QFT (sub-)system with its thermal bath ($\Delta E = 0$), mathematically formalized by the “algebra doubling”, between a q -deformed Hopf algebra and its co-algebra (Vitiello G. , 2007).

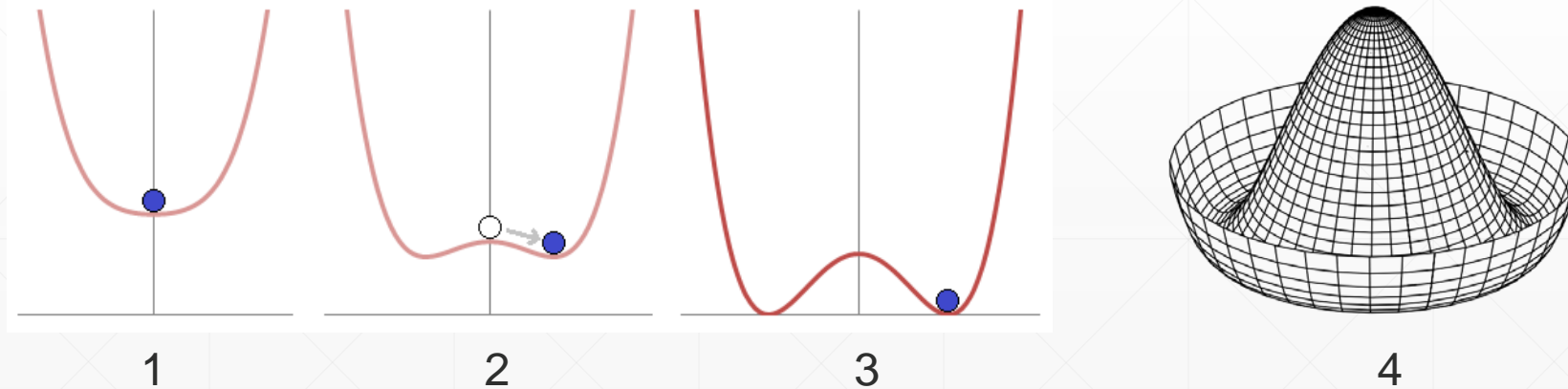
Infinitely many UIR's, SSB's and the Goldstone theorem

- The infinitely many UIR's of Haag's theorem for interacting fields in QFT coincide with the infinitely many **QV ground state conditions** through the principle of the **spontaneous symmetry breakings (SSB's)** of the QV at the ground state, related to the **Goldstone theorem**, and intuitively depicted by the so-called **Mexican-hat potential** or, equivalently, the **wine-bottle bottom potential**:



The SSB's of QV and the Mexican-hat potential and the Nambu-Goldstone bosons

- Roughly speaking, while in a classical linear system at equilibrium (minimum of potential), but far from the vacuum ground state, there is one only possible state (1), in the case of non-linear systems, because of thermal fluctuations there is a small potential (the hill in the potential), and hence there is a SSB with at least two states compatible with the ground state (2, 3), effectively, in the case of QV ground state, there are infinitely many of them (4). Now, the passage from one to the other state, i.e., a SSB of the QV, implies the presence of at least **one massless, scalar** (non energetic) **Nambu-Goldstone boson (NGB)** – effectively, **a condensate of many NGB's** in the case of many-body and condensed matter systems.



Dynamic stability of macroscopic dissipative structures in QFT

- Therefore, because the mass and the energy of the correlation NGB's is **in any case negligible** (and in the infinite volume (continuous) approximation even **null**), **their condensation does not imply a change of the energy state of the system**. This is the fundamental property for understanding how, not only the stability of inorganic structures such as crystals, magnets, ..., but also the relative stability of **the organic matter structures/functions**, at different levels of its self-organization (cytoskeleton, cell, tissue, organ...: see lecture notes §2.2.6), can depend on such basic **dynamic principles**.
- In fact, all this means that, if the QV symmetric state is a **ground state**, also the ordered state, after the symmetry breakdown and the instauration of the ordered state, **remains a state of minimum energy**, so to be **stable** in time. **In kinematics terms, it is a stable attractor of the dynamics**.
- Finally, because NGB condensates mediate **long range correlations (phase coherence domains)** among the microscopic elements of field matter, they implies a **dynamic change of scale** → crystals, fluids, magnets, superconductors, living systems... are macroscopic complex, non-linear systems whose behavior/properties depend on their microscopic quantum components.
- In other terms, QFT can give the lacking microphysical, quantum foundation to the phenomenological notion of **dissipative structures** in far from equilibrium dynamic systems in chemistry and biology, defined for the first time by the Nobel Prize Ilya Prigogine during the 60's of last century (see Ref.4)

Coherent states (QM) and phase coherence domains (QFT) in the physics of the living matter

- QFT interpretation of the physics of living matter aims at completing the panorama of **molecular biology** and of its countless successes in the comprehension of the **microscopic structures of biological systems** at the cellular and subcellular level, all related to the **statistical and probabilistic methods (diffusive methods for morphogenesis** introduced by A.M. Turing), and to the laws of **molecular kinetics**. All this is naturally in continuity with the study of **coherent states** in QM. Also Schrödinger equation and its coherence is indeed a **statistical not dynamic entity**.
- These methods, however, **are not able in principle** to reckon with the “systemic phenomena” of *biological processes* emerging at the *mesoscopic* and *macroscopic* level, **all related to the emergence of dynamic “coherence” phenomena**. These are very complex because related to the **self-organizing dynamic processes of temporal ordering** — such as, for instance, the strict chaining of specific chemical reactions — **and of spatial ordering** — such as **the coordination of cells in tissues**, at level of structures, or, at level of **the functional coordination**, the individual self-organization of the **immune system**.

From *kinetic* molecular biology to *dynamic* molecular biology

- In Vitiello's terms:
 - “The great challenge that modern molecular biology **is not yet able to answer, consists in the emerging of complex, macroscopic functional properties** of the microscopic biochemical activity, ruled by the probabilistic laws of the molecular kinetics” ((Vitiello G., 2010), p. 14).
- The tremendous and successful effort of the bio-molecular research of individuating at cellular and sub-cellular level all the microscopic structures of living matter is like to pretend to understand the social structure of a city by completing **its phone directory**. Similarly, the taxonomy of biochemical structures, even if it was complete, **is not sufficient** for understanding the **dynamic coherence** of the mesoscopic and macroscopic structures and functions of the living matter (Del Giudice).

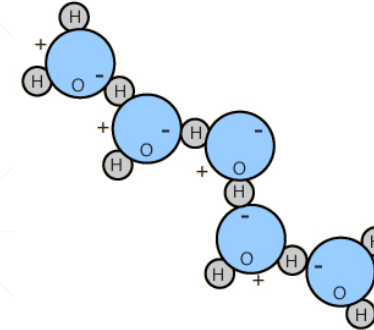
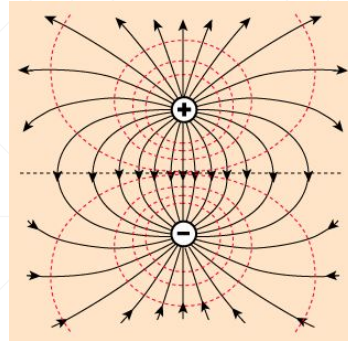
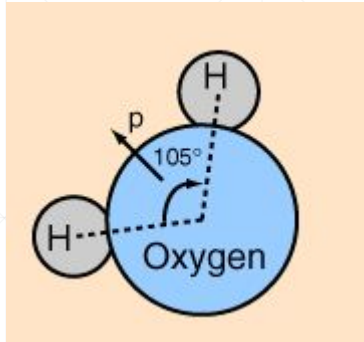
QFT principles of living matter dynamics

- The start point of QFT approach to living systems consists thus in the threefold evidence, the first two being expressions of common-sense evidence, according to which:
 - 1. **The biological systems are *open systems***, in continuous exchange of matter-energy with the external environment. In other terms, they are *dissipative systems* with energy *balance* as necessary condition for avoiding stress conditions.
 - 2. **All the macromolecules (proteins) constituting the living systems *become biologically active only if immersed in a water matrix***, an evidence that is not only immediate for whichever biology student ever entered a biology lab, but to everybody who knows the immediate negative effects of dehydration.
 - 3. The strict link between water and living matter depends on the fact that both water molecules (constituting almost the 70% of the living body weight, and more than the 95% of its molecular weight), and all the macromolecules of the living matter **are endowed with the electrical dipole momentum**. That is, because their asymmetric structure, they present a spatial distribution of electrical charge, with a positive and negative pole: **they are “polar molecules”**.

Water: its kinetic properties

- The function of water from the **chemical kinetics** standpoint:
 - Water serves **as the solvent for sodium chloride (salt) and other substances** so that the fluids of our bodies are **similar to sea water**. This leads Hill and Kolb (Hill & Kolb, 2001) to refer jokingly to us as "walking bags of sea water". Water, for instance, serves to suspend **the red blood cells to carry oxygen** to the cells. It **is the solvent for the electrolytes and nutrients** needed by the cells, and also **the solvent to carry waste material away from the cells**.
 - With water as the solvent, **osmotic pressure** acts to transport the needed water into cells. With cells bathed in the interstitial fluid, **diffusion contributes to carrying needed molecules into the cells**. When more complex mechanisms control the transport of molecules across the membranes into and out of cells, **the presence of water as the surrounding medium and solvent is essential** (see (Hill & Kolb, 2001), ch. 13).

Water: its dynamic properties. The electric dipole



(Left) Asymmetric structure of the water molecule with the direction of the dipole momentum p pointing toward the more positive H atoms, that creates a positive charge. (Center) The electric potential of a dipole (black lines) show a mirror symmetry about the center point of the dipole. The dipole electric field lines are everywhere perpendicular to the electric field lines (dotted red lines). (Right) Water molecular bond is depending on the dipole momentum, because of the asymmetric distribution of the dipole charges in each molecule. From it, depends a lot of typical water properties. For instance, the property of the surface water film (e.g., on the spherical surface of a drop of water), because the water molecules of the surface, not having other molecules over them, have a reciprocal molecular bond stronger than the lower ones. (Images are from the item “Electric Dipole” in the educational site “Hyperphysics”, hosted by the Dept. of Physics and Astronomy at the Georgia State University: <http://hyperphysics.phy-astr.gsu.edu/hbase/hframe.html>).

Water as «matrix of life» (Szent-György)

- However, to justify the most pretentious connotation of water as “**the matrix of life**” given by the Nobel Laureate A. Szent-Gyorgyi, much more is required. **It is necessary a *dynamic* approach to atoms and molecules binding**, in their interaction with **the electromagnetic field**, justifying coherently **a scale change, from the microscopic one, to the mesoscopic and macroscopic scales**, where the more complex life structure and functions are given.
- The starting point was the original intuitions of **H. Frölich** (1968, 1988) model developed by the researches of another pioneer in this field, **F. A. Popp**, who first coined the evocative term of “**biophotons**” for denoting the **electromagnetic emissions** of the living matter (Popp & Yan, 2002; Yan, et al., 2005).
- The most interesting aspect of the Frölich model consists thus in the possibility that ***long-range coherence phenomena* emerge as dynamic effects in the biological matter.**

DWQ (polarons) as Nambu-Goldstone bosons of phase coherent domains in living matter I

This means that quantum dynamics generates among the elementary components (the electric dipoles of water and of biomolecules controlling the inter-molecular binding) large-scale correlations (“large” as to the characteristic dimensions of the components, and hence till some hundreds of micron): in such a way we have “in-phase”, i.e., *coherent*, motions and oscillations. The elementary components are thus correlated, and assume a “collective” behavior characterizing their “whole” as such. We are faced, in such a way, with a *transition from the microscopic scale* of the elementary components and of their properties to the *macroscopic scale* characterized by coherence properties that can be no longer attributed to the single components, but to the system itself (Vitiello 2010).

- E.g., in non living condensed matter - that is in systems displaying **at the macroscopic level an high degree of coherence** related to **an *order parameter*** different from the density of electric polarization proposed by the Frölich model for the living matter.
- In crystals, the “order parameter”, that is the macroscopic variable characterizing the new emerging level of matter organization, **is related to the *matter density distribution***. In fact, in a crystal, the atoms (or the molecules) are “ordered” in well-defined positions, according to a *periodicity law* individuating the crystal lattice.

DWQ (polarons) as Nambu-Goldstone bosons of phase coherent domains in living matter II

- In the case of a **magnet**, the dynamic constraint from which the order parameter emerges, is the prevailing orientation of the ***magnetic (not electric) dipole of the electrons***, according to the direction to which the magnetization vector is pointing.
- Over the critical temperature, also the magnet ordering get lost, since the electrons are free to orient their magnetic dipole in whichever direction. The system so recovers its most symmetrical state in which all the directions are equivalent as to the whole, i.e., they can interchange among each other, without affecting the properties of the whole. In other terms, the elements lose their correlation, their dynamic ordering, as well as the information related to such an ordering.
- So, any process of *dynamic ordering*, and of *information gain*, **is related with a process of *symmetry breakdown***. In the magnet case, the “broken symmetry” is the rotational symmetry of the magnetic dipole of the electrons, and the “magnetization” consists in the correlation among all (most) electrons, so that they all “choose”, among all the directions, that one proper of the magnetization vector.

DWQ (polarons) as Nambu-Goldstone bosons of phase coherent domains in living matter III

- Finally, whichever dynamic ordering among many objects implies an “order relation”, i.e., a *correlation* among them.
- What, in QFT, at the *mesoscopic/macrosopic level* of condensed matter is denoted as *correlation waves among molecular structures* and their chemical interactions, at the *microscopic level* any correlation, and more generally any interaction, is mediated by densities of *quantum correlation particles*: the “**NGB**” (Nambu, 1960; Goldstone J. , 1961; Goldstone, Salam, & Weinberg, 1962), with mass — even though always very small (if the symmetry is not perfect in **finite spaces**) —, or *without mass at all* (if symmetry is perfect, in the abstract **infinite space**).
- As we know, NGB, as the correlating quanta, **are not mediators of the energy interactions** among the elements of the system like gauge bosons (photons): they determine only **the (formal) modes of energetic (causal) interaction among them**.

DWQ (polarons) as Nambu-Goldstone bosons of phase coherent domains in living matter IV

- So, any symmetry breakdown in the QFT of condensed matter of chemical and biological systems **has one only gauge boson mediator** of the underlying energy exchanges, the **photon**, since they all are **electromagnetic phenomena**.
- However, the phenomena here concerned, from which the emergence of *macroscopic* coherent states derives, implies the generation, effectively the *condensation*, of NGB, **acquiring a different name** for the different mode of interaction, and hence of coherent states of matter fields they determine – *phonons* in crystals and fluids, *magnons* in magnetes, ***polarons*** – or ***dipole wave quanta (DWQ)*** - in biological matter, etc.
- So, despite the correlation quanta are **real particles**, observable with the same techniques (diffusion, scattering, etc.), not only in QFT of condensed matter, but also in QED and in QCD like the other quantum particles, wherever we have to reckon with broken symmetries (Goldstone, Salam, & Weinberg, 1962), nevertheless **they do not exist outside the system they are correlating**. For instance, without a crystal structure (e.g., by heating a diamond over 3,545 °C), we have still the component atoms, but no longer phonons.

DWQ (polarons) as Nambu-Goldstone bosons of phase coherent domains in living matter V

- Essentially for this reason of vanishing without residuals with the phase coherent domains they constitute, NGB's, are sometimes called “**quasi-particle**”. On the contrary, because the gauge bosons are *energy* quanta, they cannot be “created and annihilated” without residuals like the correlation quanta.
- Better, in any quantum process of particle “creation/annihilation” in quantum physics, what is conserved is the energy/matter quantity, mediated by the energy quanta (gauge bosons), not their “form”, mediated by the correlation quanta (Nambu-Goldstone bosons). Also on this regard, a **dual ontology** is fundamental for avoid confusions and misinterpretations.
- Effectively, in the dual ontology, any transformation (phase transition) always induced by an acting causality and hence by an energy-matter exchange, **the old “form” as ordering relation (correlation) of material parts**, simply vanishes, differently from the material substratum that is always **conserved under the new “form”**, generated by the process.

From genetics to epigenetics in biological sciences

- QFT is a unique theoretical framework embracing **cosmology** and physical systems from the **microscopic** (relativistic realm), to **mesoscopic** (many body systems), to **macroscopic** (condensed matter systems) levels of matter organization.
- QFT plays an essential role also in explaining the physical mechanism of **the epigenetic phenomena** in living matter:
 - The cells in a multicellular organism have **nominally identical DNA** sequences (and therefore the same genetic instruction sets), **yet maintain different terminal phenotypes**. This non-genetic cellular memory, which records developmental and environmental cues (and alternative cell states in unicellular organisms), is the basis of epi-(above)–genetics. The lack of identified genetic determinants that fully explain the heritability of complex traits, and the inability to pinpoint causative genetic effects in some complex diseases, suggest **possible epigenetic explanations for this missing information**. This growing interest, along with the desire to understand the “deprogramming” of differentiated cells into pluripotent/totipotent states, has led to “epigenetic” becoming shorthand for many regulatory systems involving DNA methylation, histone modification, nucleosome location, or noncoding RNA. (...) Reprogramming is also critical for developmental phenomena such as imprinting in both plants and mammals, as well as for cell differentiation, and is linked to the establishment of pluripotency in gametes and zygotes (Riddihough & Zahn, 2010, p. 611).

QFT in biological systems and epigenetics

- The basic evidence for applying QFT in biological matter, as a particular type of condensed matter, is the emission of very low **electromagnetic signals** from all the molecules (proteins) constituting the organic matter.
- From this evidence, **epigenetic study** consists ultimately in the systematic, theoretical and experimental study about how **the higher levels of bodily organization of the individual**, during its ontogenetic development, **have a feedback onto the genetic load of its own cells**, via bio-chemical, but also **electromagnetic signals** (Ventura, et al., 2005) (Maioli, et al., 2011), so to orient the genetic expression of DNA **in an absolutely individual way**.
- **Particularly**, the emission of very low frequency **electro-magnetic signals (EMS)** by **the DNA of some viruses and bacteria**, seems to play a decisive role also in terrible diseases like AIDS, generated by the HIV virus DNA continuous recombination, as the Nobel Prize Luc Montagnier first discovered (Montagnier, et al., 2011).

An amazing evidence: QFT and AIDS disease I

- Luc Montagnier earned the Nobel Award in 2008 for the discovery of the HIV virus. Montagnier's successive discovery is related to the well-known amazing **role that water has for the stability of the double helix structure of the DNA.** The interaction of the water molecules through **hydrogen bonds is in fact different for each DNA base.**
- Now, Montagnier amazing discovery on this regard, is that it is sufficient a **background electro-magnetic field on only 7Hz**, that is natural in human environment, to allow the formation of **small, stable water moles nanostructures** (20<100 nm), **via a resonance phenomenon** with the EMS emitted by DNA sequences (effectively short HIV virus DNA sequences, of about 104 base pairs, immersed in highly purified water at a given dilution).

An amazing evidence: QFT and AIDS disease II

- They are able to emit on their own **EMS identical to those emitted by the original DNA sequences**, so to save and transmit **faithfully DNA genetic information**.
- In fact, by adding to the test tube, containing only the water nanostructures, all the single components necessary for synthesizing the DNA through the chain reaction of polymerases, **it was possible to obtain an exact copy** (at 98% in average, only 2 different nucleotides over 104) of the original DNA sequence.
- The hypotheses is that such HIV DNA sequences are able to recombine themselves with the receiving lymphocytes in the blood, **so to form a complete DNA and to trigger a devastating infection**, starting from only few infected cells — in the limit, **also one**. These results are obtained in tens of experiments in different labs, all over the world.
- Of course, such a discovery, because of the evident economic implications for pharmaceutical industries, and because of its similarity with Jacques Benenviste's hypothesis of "water memory", **excited a fierce debate** and further studies are required.