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Is the hydrogen atom an archetype for the Universe?

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Abstract

In the 20th century two fundamental scientific theories were formulated: one in the beginning of this century and the other in its 7th decade. The first theory was proposed by Niels Bohr and many other collaborators and was named Atomic Theory of Matter. The other is known as the theory of Life. Both theories are based on the same fundamental Principles of Mathematics, Physics and Chemistry.

The Atomic Theory is based on Quantum Physics and the archetype is the hydrogen atom where the nucleus consists of a proton (or a proton isotope) and the electrons move around it. In the case of Life it was found that a somehow similar mechanism is used: A class of homeotic genes (the so-called HOX genes) are activated following the Anterior –Posterior order in the DNA genome. E.B. Lewis discovered that this Hox gene order in the genome is collinearily activated in the early embryogenesis following the head-to-tail order. Lewis discovered this strange property analyzing the Bithorax complex in the Drosophila fruit fly. Later, it was established that this property is widespread in most animals particularly in the Vertebrates.

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Introduction- Historical background

A) In the first decade of the 20th century Niels Bohr formulated the Atomic Theory of Matter based on the Quantum Theory. One of Bohr's genius disciples, Werner Heisenberg, formulated the Uncertainty Principle according to which it is impossible to measure accurately at the same time both the position and the speed of a particle [1]. The most eminent opponent of this principle was Albert Einstein who conceived in this decade the genial Special Relativity Theory. Einstein trusted only confirmed measurements and compacted his stand in its dictum "God does not play the Universe in dice".

B) According to the archetypal model of the hydrogen atom, the electron is turning around the proton which

is fixed in the centre of the atom. The distance between the proton and the electron is relatively 'enormous' (about 52.9x10-12 meters) [2]. In order to compare linear distances at the atomic scale, it is useful to introduce the abstract mathematical scale sizes of the proton as compared to the distance of the electron (Bohr's radius). Bohr's atomic radius extends from the 'unity'(one 'meter') up to 4 orders of magnitude 'meters' (104) (e.g. 1 versus 10.000).

C) In 1946 the genius young theoretical physicist Freeman Dyson was the first who formulated the theory of Quantum Electrodynamics [3] Other distinguished Physicists followed independently (R. Feynman, J. Schwinger, S. Tomonaga). For their work, these 3 physicists were later awarded the Physics Nobel Prize in 1965. (Surprisingly, F. Dyson was omitted!). He was however rewarded by his appointed as Professor of Physics at the University of Princeton and its distinguished Institute for Advanced Study.

D) The atomic distances are determined by the laws of Quantum Mechanics, therefore all atoms of the same kind and atomic number (e.g. the hydrogen atoms) are identical (Stefanos Trachanas, personal communication). We do not know what happens in the other stars of the Universe.

Life on Earth

A) Besides the Bohr atomic world, in the middle of the 20th century, E.B. Lewis made a major discovery: the '4 orders of magnitude measuring rule'surprisingly applies in the quite different genetic findings in the Drosophila fruit fly [4]. A class of homeotic genes (named Hox genes) were sequentially aligning along the anterior to posterior direction on the DNA fiber in the Drosophila nucleus. E.B. Lewis noticed that this Hox gene ordering was the same with the early ontogenetic units along the anterior to posterior axis of the Drosophila embryo. The DNA nucleus and the early embryo differ spatially by 4 orders of magnitude (like the Bohr's atomic radius).

B) As early as 2001, I had proposed a Biophysical model (BM) which predicted the gradual creation of pulling Coulomb forces on Hox gene clusters [5] (Fig1). This surprising hypothesis passed unnoticed until these multiscale forces were later experimentally confirmed [6-8].

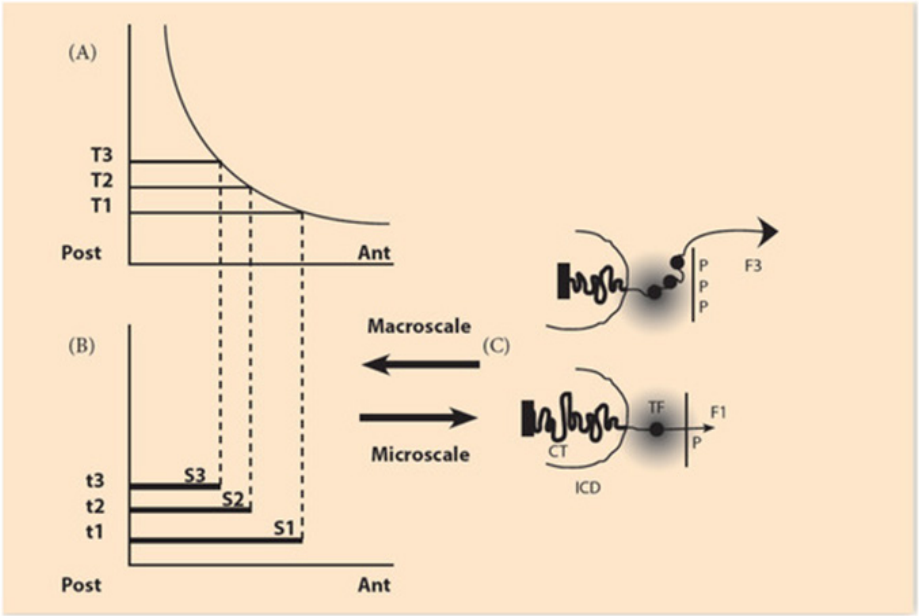

Figure 1: Morphogen gradient and Hox gene clustering (adapted from Y. Almirantis et al. Current Genomics 2013, 14. (A) Concentration thresholds (T1, T2, T3) (B) Time sequences (t1, t2, t3) and corresponding domains (S1, S2, S3) determine the Hox1, Hox2, Hox3 activation in space and time. (C) (bottom) In an anterior

cell of S1, a small force F1 pulls Hox1 (black spot) out of the chromatin territory (CT) toward the (ICD) and the (TF) (grey domain). Allocation of polar molecules P opposite the telomeric end of the Hox cluster. At a later stage (top), in a more posterior location of S3, a stronger force F3 pulls Hox1, Hox2, Hox3 out of CT in the TF. (Allocation of 3P molecules).

Extraterrestrial Life

The polymath Freeman Dyson has described various forms of Life expected in different star environments. (see e.g. the proposed Dyson sphere). In recent observations on various planetary systems, several Earth-like planets were noticed [9]. It is therefore worthwhile exploring this new scientific area.

Appendix

A wandering pathway in scientific research

I started my research career in 1961 with a grant of the Nuclear Research Center 'Demokritos' to attend a Research program in Oxford (UK) under the supervision of Professor R.J. Blin-Stoyle (FRS). The first problem that I had to handle was the nuclear fusion phenomenon

$$\text{Proton} + \text{Proton} \rightarrow \text{Deuteron} + \text{positron} + \text{neutrino}$$

which is the basic mechanism of energy release in the stars (the Sun included). I received my D.Phil. in1965 and the same year I was appointed in the Theoretical Nuclear Physics Department of 'Demokritos'. In 1968 I joined the Theory Division of CERN and in 1971 I became Corresponding Fellow of CERN and 'Demokritos'. Compared to CERN, 'Demokritos' is a small and isolated Laboratory and this was my serious concern.

In 1975 Fotis Kafatos, the eminent Biology professor of Harvard retuned to Athens and I confessed to him my concern and my wish for a change. Kafatos urged me to switch my research toward Developmental Biology which is a fascinating scientific branch in need of researchers skillful in Physics and Mathematics. After serious thought I decided to change accordingly my research focus. In 1975 I started working on the genial theory of Morphogenesis formulated by Alan Turing in 1952.

In 2001 I formulated the first version of a Biophysical Model (BM) introducing physical forces to explain the Hox gene expression in the Hox clusters. In these clusters the genes are located in order Hox1, Hox2, Hox3, along the Anterior-Posterior axis in the Drosophila genome while the Hox genes are expressed in the same order along the head to tail axis of the Drosophila early embryogenesis. This is a surprising result first observed by E.B. Lewis in 1978 [4]. It is astonishing because any biochemical mechanism alone cannot produce such correlations since the genome and embryo dimensions differ by more than 4 orders of magnitude at their initial stage of development. Lewis named this important property Spatial Collinearity. It was found that this property is quite common in most animals - the Vertebrates included.

The Hox gene clusters behave like elastic springs: when they are pulled, they expand significantly. In any wild type animal, if the cluster is pulled by a (BM) force it expands accordingly. However, it was observed that in several cancerous tissues the size of the Hox gene clusters is abnormally elongated as in the case ofacute myeloid leukemia. Thus, the variable size of Hox gene clusters is related to cancer and this finding is now intensively studied.

The wild type animals obey Noether Theory which guaranties the normal Hox gene ordering in a Hox cluster. In mutagenesis however, normal ordering is violated: (Hox1, Hox2, Hox3, …) undergoes to (Hox1, Hox3, Hox2,.) as e.g. in the Antennapedia mutation of Drosophila.

I have recently proposed to JC Smith an experiment to further test BM. JC Smith, an expert in the field, found

the proposal interesting but he could not perform the experiment because he was closing his Laboratory in Cambridge University (UK) due to his retirement. (He remains however in the Francis Crick Institute as an Emeritus Fellow).

In 2001 I proposed the first version of BM with its associated pulling physical forces [5]. This proposal was ignored by the scientific community for several years. Only after 2010, BM was properly acknowledged mainly because many BM predictions were experimentally confirmed [6,7, 8]. I believe that in the future, BM with its pulling physical forces will continue reproducing the gene expression data of Hox clusters.

In 2021, the important phenomenon of physical tension was observed in D. Duboule's Laboratory during a cis mutagenesis in vivo experiment at the mouse HoxD cluster [9]. The origin of this physical tension is elusive. However, Duboule et al reckon that the physical forces created by BM might be responsible for this tension [9]. It is worth further examining this possibility.

I close my wandering pathway with an analogy: Niels Bohr founded the Atomic Theory of Matter with the archetype of the hydrogen atomic nucleus and the electrons moving around at a distance. The same archetype applies to the living beings according to the pulling forces of BM: the genome (DNA) is surrounded by Hox genes expressed at a distance. It is amazing that the '4 orders of magnitude' rule is preserved in both Matter and Life as if they belong to 'parallel universes'. Is this fortuitous or an obedience to an inviolable physical law?

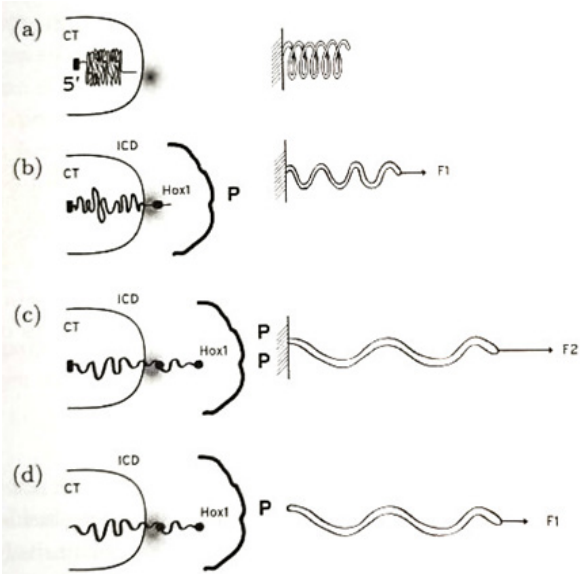

Figure 2: (adapted from S. Papageorgiou Current Genomics, 2012, 13, 245–251). Mechanical analogue of Hox cluster decondensation and extrusion. (a) Left: before activation, the Hox cluster is condensed in the chromatin territory (CT) fixed at the posterior 5' end. The transcription factory (TF) is represented by a grey domain. Right: mechanical analogue: an uncharged elastic spring is fixed at its left end. (b) Left: the cluster is slightly decondensed and Hox1 (black spot) is extruded in the interchromosome domain (ICD) in the area of the TF. The P-molecules are allocated opposite the cluster. Right: a small force F1 is applied at the loose end of the spring and expands it slightly. (c) Left: the cluster is further decondensed and the extruded Hox2 is located in the transcription factory area. Hox1 moves off the TF domain and its activation is reduced. Right: a bigger force (F2 > F1) expands further the spring. (d) Left: the posterior end of the cluster is cut-off. Right: the fixed end of the spring is removed and a smaller force (F1) expands and dislocates the spring as in Fig. 2c (right).

Epilogue [11]

The modern Greek poet Odysseas Elytis (1979 Nobel prize for Poetry) wrote a Chant (Worth existing) dedicated

to his Weltanschauung idea for the whole World -- micro and -- mega. The last verse of this Chant finishes (in Greek).. 'ο Κόσμος ο μικρός ο Μέγας' (no translation needed).

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