https://doi.org/10.31871/WJRR.10.2.7

World Journal of Research and Review (WJRR)
ISSN: 2455-3956, Volume-10, Issue-2, February 2020 Pages 07-17

Levels of Composition: from Quarks to HHe^+ Molecular Ion

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***Abstract*—I present the results of an exploration of the idea that all objects of the actual and earlier Universe can be organized in levels. Previous works dealing with 'combination', 'whole', 'part' and 'level' are commented. The analysis of the levels is addressed by creating time-dependent and time-independent models. The time-dependent model starts using the Planck Epoch as a starting point. Here, each level is more or less associated with an Epoch of the Universe. This form of analyzing the appearance of the many particles and forces is attractive, but I think that in the moment when more complex structures are formed the level model could fail. The time-independent model uses all elementary particles as components of the lowest level, L_1. The other levels are formed by fusion or clustering of members of the lower levels. The analysis of the models showed that the statement that 'anything belonging of any level except the lowest one can be decomposed into things belonging to the next lower level' is not correct. Some considerations about emergency and complexity are presented.**

***Index Terms*—Atomic nuclei, atoms, complexity, composition, elementary particles, emergent property, exotic atoms, exotic molecules, fundamental particles, hadrons, leptons, levels, molecules, novelty, nucleosynthesis, parts, quarks, reality, realm.**

I. INTRODUCTION

This paper is an exploration of the idea that all 'things' (or 'objects') of the actual and earlier Universe can be ordered in 'levels'. The things analyzed here are physical objects comprising the elementary particles (quarks, leptons, gauge bosons, Higgs boson, antiquarks and antileptons included in the Standard Model) and all their possible known and unknown combinations. I am aware that there is a possibility that in the future one or more new more 'fundamental' particles could be detected (gluino, chargino, wino, Higgsino, photino, etc.), but they will not alter the essential ideas of this work. Following Salvatore Rappoccio, particle physics is at a crossroads: '*the standard model (SM) explains a wide range of phenomena spanning interactions over many orders of magnitude, yet no demonstrated explanation exists for a variety of fundamental questions. Most recently, the discovery of the Higgs boson at the ATLAS and CMS detectors has addressed the mechanism of electroweak symmetry breaking, but there is no explanation for why the scale of its mass is so much different from naive quantum-mechanical expectations (the "hierarchy problem"). Dark matter (DM) remains an enigma, despite extensive astronomical confirmation of its existence. Neutrino masses are observed to be nonzero, and elements of the Pontecorvo–Maki–Nakagawa–Sakata matrix have been measured, but these masses are not easily accounted for in the SM. Unification of the strong and electroweak forces is expected, but not yet observed nor understood; such models often predict the existence of yet-to-be-observed leptoquarks (LQs) or proton decay. Furthermore, there are unexpected observations that are not explained in the SM, such as the baryon asymmetry, anomalies in the decays of bottom-quark hadrons, a discrepancy in the anomalous magnetic moment of the muon (g-2), and the strong CP problem. Even further, there are open questions about long-standing observations, such as whether or not there is an extended Higgs sector, why there are multiple generations of fermions with a large mass hierarchy, and why no magnetic monopoles are observed to exist. For these reasons, the SM is considered to be an effective field theory, and that physics beyond the SM (BSM) should exist*' [1]. For an stimulating and detailed discussion about material things see the book of van Inwagen [2] and the writings collected by Castellani [3].

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II. WHOLES AND PARTS

The concept of '*combination*' is closely associated to the concepts of '*whole*' and '*part*'. Many authors have written about these subjects, but I will mention (and perhaps use) here some definitions proposed by Husserl in his *Logical Investigations* [4-6]. "*Objects can be related to one another as Wholes to Parts, they can also be related to one another as coordinated parts of a whole. These sorts of relations have an a priori foundation in the Idea of an object. Every object is either actually or possibly a part, i.e. there are actual or possible wholes that include it*". I think that these statements are fully valid within the domain covered by this work (i.e., inanimate objects). "*Not every object, on the other hand, need perhaps have parts, and we have therefore the ideal division of objects into the simple and the complex*". By *simple objects* we shall understand here the fundamental particles. Therefore, "*the terms 'complex' and 'simple' are therefore defined by the qualification of having parts or not having parts*" [4].

Husserl complicates this view when he introduces a second understanding of these terms that happily, and at the level we are working, we do not need (yet). Husserl continues: "*We interpret the word 'part' in the widest sense: we may call anything a 'part' that can be distinguished 'in' an object, or, objectively phrased that is 'present' in it*". By '*distinguished*' we shall understand for the microscopic level '*experimental evidence should be interpreted as if*' because we have no direct knowledge of them, contrary to the case of macroscopic objects surrounding us. For example, let us consider the benzene molecule, C_6H_6. Chemists normally say that benzene *is composed* by six carbon atoms and six hydrogen atoms arranged in a certain way. Isolated hydrogen and carbon atoms have their electrons distributed in a certain way (in the atomic orbitals). The question is if we can or we cannot distinguish these twelve atoms *inside* a molecule of benzene. A full analysis of an X-ray diffraction study of benzene provides us with twelve points distributed in the image in such a way that we assume that they correspond at least to the nuclei of the twelve atoms. Therefore, and in a first approach, we may state that we have apparently *distinguished* 12 objects in the X-ray diffraction study of an object called '*benzene molecule*'. The question if these atoms are '*present in*' is a little more complicated problem. At most we may state that the nuclei of the twelve atoms are '*present in'* but, regarding the electrons, the answer is not easy because the electrons are distributed among the nuclei and in a totally different way than in the isolated atoms. Therefore, instead of saying that hydrogen and carbon are '*present in'*, we may say that the atoms are present '*in potentia*'. Only by carrying out any arbitrary partition of the total electronic density we could be able to '*distinguish*' twelve different atoms.

The case of macroscopic objects seems to be simple but appears to be time-dependent, such as the cases of two neutron stars orbiting each other closely or of me having a piece of cake in the hand. The neutron stars finish as a heavier neutron star or a black hole and the piece of cake devoured by me.

The knowledge that a '*whole*' can be one of the parts of a bigger '*whole*' can be connected with the concept of 'level' (the idea of what is the kind of relationship between the '*size*' of a whole and the '*size*' of its composing parts/wholes has not been fully analyzed as far as I know). Another interesting ideas developed by Husserl are about '*mediate/immediate*' and '*nearer/more remote parts*' of a whole [5, 6].

III. Levels

The interest in the level structure of reality has produced a variety of contributions to the specialized literature. In the abstract and/or introduction section of several papers I read (I will not cite them) the authors claim to be presenting a new and solid view on the subject of levels. Frankly speaking (or writing) their content is *much ado about nothing* [7]. Earlier works by Lloyd Morgan [8], Samuel Alexander [9], Charlie Dumbar Broad [10], William Morton Wheeler [11], Roy Wood Sellars [12], Oliver Reiser [13], William Pepperell Montague [14], John Elof Boodin [15] and Jan Christiaan Smuts [16] are still greats sources of inspiration. I will mention only what I consider are the main contributions to the idea of 'levels' because they present ways to create and order them and suggest some rules and properties they must satisfy.

In 1925, George Conger presents the first attempt to clarify what 'levels' could mean [17]. He carried out an analysis and discussion of Sellers, Morgan and Alexander's contributions. As an answer of the question '*what levels does the world exhibit?*' Conger mentions that there is no consensus about what levels are actually found in the world. For example, Alexander distinguished six levels and perhaps a seventh one (space-time, primary qualities, matter, secondary qualities, life, mind and 'deity') [9]. But, it is important to mention that Conger remarks that Sellars, Alexander and Morgan agree that the realms of matter, life and mind constitute '*different levels in the universe'* [8, 9, 12].

Conger proposes a world composed by twenty-five levels, enumerated as follows: *'(1) energies, (2) electrons, (3) atoms, (4) molecules, (5) astronomical masses, or bodies, such as planetesimals, (6) solar systems, (7) star clusters, (8) galaxies, or great spiral nebulae, (9) possibly one or more groups of spiral nebulae - that is, one or more astronomical "universes." Then, in the biological realm, let us say (10) organic compounds, (11) infra-cellular organisms, such as Mathews calls micelle, (12) unicellular organisms, (13) multicellular organisms, (14) plant-and-animal groups, and then several levels exhibiting more complex types of social organization, such as (15) families or tribes, (16) nations or races, and, one might go on to say, (17) "The Great Society. " Once more, in the neuropsychological realm, one might add levels for (18) specialized cells, (19) nervous areas where the conduction is indiscriminate or reversible, (20) reflex arcs, and then doubtless for several different levels of higher neural synthesis, providing for (21) complex reflexes such as are apparently operative in perception and language-reactions, (22) instinctive-emotional complexes, (23) sentiments, (24) values, and, as a final term, (25) personalities*' [17].

Oppenheim and Putnam presented a system of levels with several characteristics [18]. There are some constraints for levels:

1. There must be several levels. The minimal number is two for obvious reasons.
2. The numbers of levels must be finite. For a set of levels generated for the analysis of the composition of physical objects this requirement is not necessary but, considering the physical structure of the Universe, it is probably true. In 1952 the German genius Erwin Schrödinger introduced the concept of 'multiverse' [19]. Some classification schemes for the various theoretical types of multiverses and universes that they might comprise have been suggested [20-22]. Some researchers argue that this concept is a philosophical conception rather than a scientific hypothesis because it cannot be empirically falsified. To this we can reply that when we have a more complete theory of multiverses (and there are many of them) and derive some conclusions, we possibly can design experimental settings to test them. *Anyway, and as a whole, our multiverse should be the top level.*
3. There must be a unique lowest level.
4. Anything belonging of any level except the lowest one can be decomposed into things belonging to the next lower level. I am not sure if *all* decomposition products *must* belong to the next lower level.
5. Nothing on any level should have a part on any higher level.
6. The levels must be selected in a way which is justifiable

from the standpoint of present-day empirical science.

They add that the highest level to which a thing belongs will be considered the *proper* level of the thing. From top to down, Oppenheim & Putnam present the following list of levels satisfying the above six conditions: social groups, (multicellular) living things, cells, molecules, atoms, elementary particles [18]. My opinion is that this list, from the point of view of material composition, is very primitive and incomplete. For example, the Sun, the Milky Way and the black holes have no a place in this list.

In 1959 Bunge, in his book Metascientific Queries, analyzes the question *Do the levels of science reflect the levels of reality*? [23]. As I am not interested for the moment in this problem, I will mention only some Bunge's statements about levels (Chapter 5 of [23]). 'Level' is defined as "*a section of reality characterized by a set of interlocked properties and laws, some of which are peculiar to the given domain, and which are assumed to have emerged in time from (lower or higher) levels existing previously*". He adds also that "*the higher levels are rooted to the lower ones, in the sense that they could not have arisen without the latter – which does not preclude, however, the reactions of higher on lower levels*" and that "*in the higher level a larger number of qualities is involved, among which the new ones (the emergent qualities) specify the new level; however, the emergence of a new level does not consist in the addition of a new set of qualities: some of the properties characterizing the underlying level may be lost in the new one*". I must confess that this was the chapter attracting my attention to the question of levels. But I must remark that apparently the use by Bunge of a somewhat narrow idea of what is reality has led him, or to some confusion, or to a misunderstanding or simply to the non-understanding of some ideas that belong to philosophy. That has led him to enunciate what can perfectly be considered an edict discarding some philosophical currents [24, 25]. But not all philosophical statements can be reduced to set theory! (*Philosophy is like being in a dark room and looking for a black cat and science is like being in a dark room looking for a black cat while using a flashlight with limited range*, Anonymous, I added '*with limited range'*).

To clarify the concept of level Bunge carried out a semantic analysis of nine meanings of the term 'level" [26]. In his treatise *Scientific Research* Bunge mentions the ontological hypothesis that "*reality, such as known to us today, is not a solid homogeneous block but is divided into several levels, or sectors, each characterized by a set of properties and laws of its own*" ([27] p. 293). He mentions the physical, the biological, the psychological and the sociocultural levels. Bunge repeats some of the conditions that the levels should meet. Every level may be divided into sublevels. *The higher levels are rooted in the lower ones* ([27] p. 293). *The higher levels are not autonomous but depend for their existence on the subsistence of the lower levels* ([27] p. 293). I must note that, if we take '*subsistence*' in the sense of '*the condition of remaining in existence*' this requirement seems not to be necessary in some cases. Next, Bunge enumerates several principles to deal with levels ([27] p, 204). The principle of level transcendence states that *if one level is insufficient for the truthful account of a set of facts; scratch its surface in search for contiguous levels* (lower ones I presume). The principle of level contiguity states that *do not skip levels, that is, do not miss the intermediate levels when establishing interlevel relations* ([27], p. 294).

A very clever analysis was presented by James Feibleman [28]. He suggested the following nine rules for levels (there are more rules).

1. Each level organizes the level or levels below plus one emergent quality.
2. Complexity of levels increases upwards.
3. In any organization the higher level depends on the lower.
4. In any organization, the lower level is directed by the higher.
5. For an organization at any given level, its mechanism lies at the level below and its purpose at the level above.
6. A disturbance introduced into an organization at any one level reverberates at all the levels it covers.
7. The time required for a change in organization shortens as we ascend the levels.
8. The higher the levels, the smaller its population of instances.
9. It is impossible to reduce the higher level to the lower.

A number of opinions about levels from different authors overlap. It seems not necessary to take position for the moment about what others said.

IV. Building Levels

My approach to this problem is probably not new. It simply consists in building a concrete structure of levels to give an account of the composition of physical objects, finding and discussing the problems associated to this task. From the level-by-level analysis the ideas about novelty, emergence and complexity will be introduced when necessary. I have not any aversion against treating ideas as if they floated freely in the *mental space*, but I feel that a well-grounded example may throw some light on this problem.

It seems that this task can be accomplished using a time-dependent or a static (time independent) model. The static approach involves creating a list of all known objects existing (i.e., the Moon) or not (i.e., dinosaurs) currently and see if they can be placed in composition levels built from the lowest level.

The time-dependent approach consists in building levels analyzing the chronology of the universe in terms of epochs. This will allow characterizing the levels of each epoch. Figure 1 shows a diagram of evolution of the observable part of the universe from the Big Bang [29].

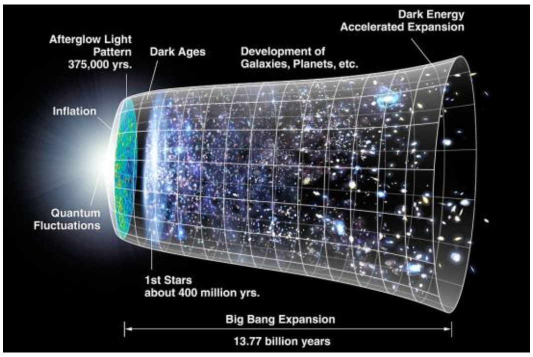

Figure 1. Diagram of evolution of the universe [30].

V. Combination (Clustering) and Fusion

Bunge defines an *assembly process* is one in which two or more things join to form a new thing [31]. There are at least two ways to do this. All objects, apart from fundamental particles, are formed by combination (or clustering) and/or by fusion [32]. For combination or clustering we shall use the following nomenclature:

$$O_1 = \bigoplus_{i=1}^{N} x_i$$

This means that object O_1 is formed by the combination or clustering (denoted by $\oplus$) of N objects x_i. The Solar System is an example (Figure 2, [33]).

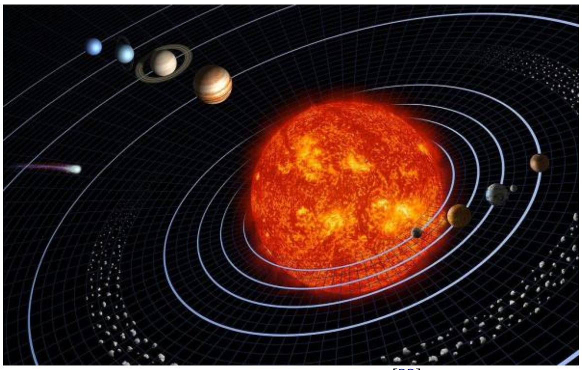

Figure 2. The solar system (not to scale [33]).

The Sun, planets, comets, moons, asteroids, etc. keep their own identity but at the same time they form a group of objects ruled by gravity (described by Newton´s theory, general relativity, Brans–Dicke theory, etc.). Another example is the atoms: the nuclei and electrons attract themselves by the electromagnetic force (quantum mechanics rules their behavior, Figure 3 [34]).

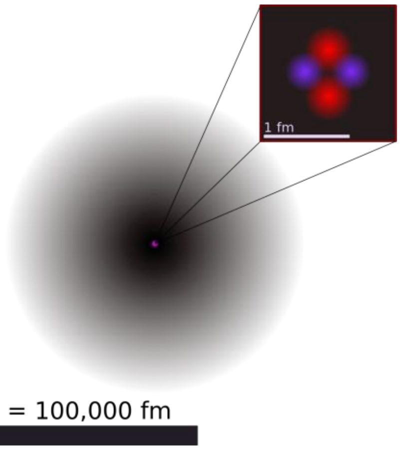

Figure 3. An illustration of the He atom, portraying the nucleus (pink) and the electron cloud distribution (black) [34].

Nucleus and electrons keep their identity. Note that in the case of the nucleus, protons and neutrons are bound together by the nuclear force (i.e., the nucleus can be considered as an aggregate of protons and neutrons). This corresponds to Bunge's juxtaposition or physical sum [32].

What condition could we impose to guarantee that the identities of the abovementioned objects are kept when they combine? I propose that the core intension of the isolated objects must be conserved when they form part of a cluster [27, 35]. This condition will be analyzed below. *For these kinds of objects we state that they form a system.* Also, if we understand *complexity* as a concept used to characterize an object formed by many parts that interact in several different ways, we may state that the product of clustering is more complex than the isolated objects that compose it.

For fusion we shall use the following nomenclature:

$$O_2 = \bigotimes_{i=1}^{M} y_i$$

This means that object O_2 is formed by the fusion ($\otimes$) of M objects y_i. I think that a good example is the proton, composed of three valence quarks: two up quarks and one down quark, each one with a different color, and the gluons mediating the forces "binding" them together (Figure 4 [36]).

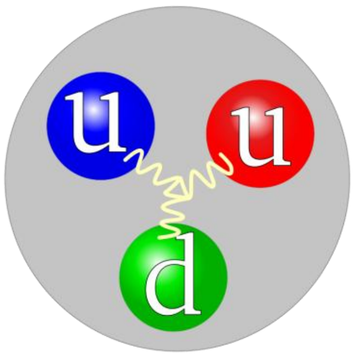

Figure 4. Composition of the proton [36].

In this case, the core intension of quarks is entirely different from that of the proton. This corresponds to Bunge's superposition or physical product [32].

Let us analyze now the more complex example of the Milky Way and Andromeda galaxies, both belonging to the class of galaxies and being systems accordingly to the above definition. It has been calculated that they will collide in about 4,000 million years. The final product of this collision (the Milkomeda, Fig. 5 [37]) will possible be a giant elliptical galaxy or maybe a large disk galaxy (there is a possibility that the Triangulum Galaxy collides first with the Milky Way but this is no important here).

Figure 5. Andromeda–Milky Way collision [37].

In this end product it is not possible to recognize the original galaxies but the intension of the three galaxies (i.e., the list of properties allowing to classify them as belonging to the class of galaxies, [27]) is the same. But, on the other hand, if we decide to include in the core intension of the Milky Way galaxy one or more *earmarks* allowing recognizing this object not only as a galaxy but also as being the Milky Way, we may say that we are in presence of a fusion. Let us note that the number of objects and the number of interactions forming the resulting galaxy increase but the number of different kinds of interactions between the objects (gravitation) does not. Therefore it seems that in the case of fusion, complexity in the abovementioned sense does not change.

Note the following example. Resulting from some circumstances, the abovementioned two neutron stars orbiting each other closely can end in a black hole (with clear changes of the core intensions and complexity and being a good example of fusion) or in a heavier neutron star (with no change in the core intensions or in complexity and being a good example of clustering).

VI. Inanimate, Living and Mind Realms as Classes

Conger remarked that Sellars, Alexander and Morgan agree that the realms of matter, life and mind constitute ***'different levels in the universe'*** (see above). The use of the term 'realm' (in the sense of world, sphere, branch, area) is quite confusing. I will begin by defining three classes called 'matter', 'life' and 'mind'. When we try to populate them with their proper members the reader will notice at once that this is not possible. Instead of this I will define the class of inanimate objects (S_i) and the class of living objects (S_l) in such a way that $S=S_i \cup S_l$. Living and inanimate objects are defined by ostentation, but we must keep in mind that we need a definition of '*being alive*' for the case of objects that are out of the human scale (they could be microscopic like viruses or too large).

In the following, and for showing the difficulties for time-dependent and time-independent approaches to levels, we shall discuss them only until at the level of isolated molecules. For the chronology of the universe I cited directly several Wikipedia entries and other web pages. Some books and scientific articles have been read [38-51] (my apologies if I made one or more mistakes when defining the Universe epochs).

VII. The Time-Dependent or Evolutionary Level Structure

The After defining level 1 (with no novelty, complexity or emergent properties), the next step consists in determining the level corresponding to each epoch after the Big Bang and its components. The creation and analysis of the core intension of the components of the different levels should be done only after their study to appreciate if they can or cannot provide important new information.

1. The Planck epoch

We shall begin our analysis after the Planck epoch 10^{-43} seconds (radiation temperature ~10^{19} GeV) after the Big Bang (BIBA). Nothing is known of this period. During this era, the four basic forces, strong, electromagnetic, weak, and gravity were united as a single force. At the end of this epoch, gravity had separated from the electronuclear force (the unification of the strong nuclear force and the electroweak force, itself a unification of weak nuclear force and electromagnetic force) [53]. There is no presently existing physical theory to describe this epoch but perhaps the hypothetical graviton (g) could 'inhabit' this level. Let us define this level as being level 1 with the class $S_1=\{g\}$. They are elementary particles with no sub structure. This level has no novelty, complexity or emergent properties by definition.

2. The Grand Unification epoch [54]

Once gravity had separated out it is thought that a single field remained, a field which is described by the Grand Unified Theory and hence this period is known as the Grand Unification Epoch (GUE). GUE starts at 10^{-43} second (radiation temperature >10^{16} GeV) and ends at 10^{-36} second after the BIBA. This is a period when the universe underwent a *phase transition* from a higher energy state to one of lower energy. Many new particles are created: free quarks, antiquarks (Table 1) and photons (γ) in equilibrium with each other. Quarks are called up (u), down (d), strange (s), charm (c), bottom (b) and top (t).

Table 1. Quarks.

	Q	D	U	S	C	B	T	Mass MeV/c^2	Spin
d	-1/3	-1	0	0	0	0	0	4.8	1/2
u	2/3	0	1	0	0	0	0	2.3	1/2
s	-1/3	0	0	-1	0	0	0	95	1/2
c	2/3	0	0	0	1	0	0	1.275	1/2
b	-1/3	0	0	0	0	-1	0	4.18	1/2
t	2/3	0	0	0	0	0	1	173.07	1/2

Table 1 shows six quarks with the charge (Q), 'downess' (D), 'upness' (U), strangeness (S), charm (C), beauty (B) and truth (T) [55]. Table 2 shows a different ordering of quarks [55]. Flavour quantum numbers [isospin (I_3), charm (C), strangeness (S, not to be confused with spin), topness (T), and bottomness (B′)] are assigned to certain quark flavors, and denote qualities of quark-based systems and hadrons. The baryon number (B) is +1⁄3 for all quarks, as baryons (see below) are made of three quarks. For antiquarks, the electric charge (Q) and all flavor quantum numbers (B, I_3, C, S, T, and B′) are of opposite sign. Mass and total angular momentum (J; equal to spin for point particles) do not change sign for the antiquarks [55].

Table 2. Quarks.

Symbol	J	B	Q	I_3	C	S	T	B'
u	$1/2$	$+1/3$	$+2/3$	$+1/2$	0	0	0	0
d	$1/2$	$+1/3$	$-1/3$	$-1/2$	0	0	0	0
c	$1/2$	$+1/3$	$+2/3$	0	1	0	0	0
s	$1/2$	$+1/3$	$-1/3$	0	0	−1	0	0
t	$1/2$	$+1/3$	$+2/3$	0	0	0	1	0
b	$1/2$	$+1/3$	$-1/3$	0	0	0	0	−1

The table of antiquarks is obtained by reversing all signs of Table 2. Given that each quark comes in three colors, we have a total of 36, including the corresponding antiparticles. Adding two kinds of photons (right-handed and left-handed) and the graviton, we have a grand total of 38 members for this level, called level 2. All belong to class $S_2 = \{2 \text{ photons, 36 quarks and antiquarks}\}$. All are elementary particles. The field is occasionally called the Grand Unification Field and we do not find it in the world today because it has since broken down into three other fields.

3. The Inflationary Epoch and the Electroweak Epoch [45, 56, 57]

Inflation started at about 10^{-36} s after the BIBA and lasted until about 10^{-34} s. During this very short period the universe expands by a factor of 10^{26}. The elementary particles remaining from the Grand Unification Epoch (hot and dense quark-gluon plasma) become distributed very thinly across the universe. The huge potential energy of the inflaton field was released at the end of the inflationary epoch, repopulated the universe with a dense, hot mixture of quarks, anti-quarks and gluons as it entered the EWE [58]. At this moment the list of existing particles is similar to the list of the Grand Unification Epoch. Therefore, at this point we may conserve the particle list from the previous epoch. Following the inflationary epoch the universe continued to expand, but at a slower rate.

The EWE is the period when the temperature of the universe had fallen enough that the strong force separated from the electroweak interaction (a combination of the weak interaction and electromagnetism) [53, 56]. When the strong nuclear force broke free from the weak interaction gluons appeared (there are eight types of gluons from QCD [59]). Particle interactions create large numbers of exotic particles, including $W^{\pm}$ (the positive and negative carriers of the weak force) and Z bosons (the neutral carrier of the weak force) and Higgs bosons (the Higgs field slows particles down and confers mass on them, allowing a universe made entirely out of radiation to support things having mass). The strong nuclear force uses gluons as its force carriers and is the strongest of the four forces. At this point we may define level 3 and class S_3:

$$S_3 = \{2 \text{ photons, 8 gluons, } W\pm \text{ bosons, Z boson, Higgs boson}\}$$

When the universe was about 10^{-12} seconds old, $W^{\pm}$ and Z bosons ceased to be created. The remaining $W^{\pm}$ and Z bosons decayed quickly. The EWE ends at 10^{-12} s after the BIBA.

4. Quark epoch [60, 61]

The Quark Epoch starts at 10^{-12} seconds and ends at 10^{-6} seconds (radiation temperature >100 MeV). During this epoch, the electroweak force split into the electromagnetic and weak force and the fundamental interactions of gravitation, electromagnetism, the strong interaction and the weak interaction had taken their present forms but the temperature of the universe was still too high to allow quarks to bind together to form hadrons. **Quarks, electrons and neutrinos (and their antiparticles) form in large numbers as the universe cools off to below 10 quadrillion degrees**. Quarks and antiquarks annihilate each other upon contact but a surplus of quarks (about one for every billion pairs) survives, which will ultimately combine to form matter (baryogenesis). Quarks were listed in Tables 1 and 2. Table 3 shows the leptons (their respective antiparticles are identical, except that they carry the opposite electric charge and lepton number).

Table 3. Leptons.

Name	Symbol	Antiparticle	Charge
Electron	e^-	e^+	-1
Muon	μ^-	μ^+	-1
Tau	τ^-	τ^+	-1
Electron neutrino	ν_e	$\bar{\nu}_e$	0
Muon neutrino	ν_μ	$\bar{\nu}_\mu$	0
Tau neutrino	ν_τ	$\bar{\nu}_\tau$	0

At this point we may define level 4 and class S_4:

$$S_4 = \{2 \text{ photons, } 12 \text{ leptons and antileptons}\}$$

5. Hadron epoch [61, 62]

It started approximately 10^{-6} seconds after the Big Bang and ends at 1 sec after the BIBA. The temperature of the universe had fallen sufficiently to allow the quarks to bind together into hadrons and anti-hadrons (i.e., quarks became confined within hadrons (radiation temperature >1 MeV). Most of the hadrons and anti-hadrons were then eliminated in annihilation reactions, leaving a small residue of hadrons. The elimination of anti-hadrons was completed by one second after the BIBA. After the majority of hadrons and antihadrons annihilate each other at the end of the Hadron Epoch leptons (such as electrons) and antileptons (such as positrons) dominate the mass of the universe. As electrons and positrons collide and annihilate each other, energy in the

form of photons is freed up and colliding photons in turn create more electron-positron pairs. The Universe is filled with pions (π mesons), protons and neutrons, charged leptons (electrons, muons) and their associated neutrinos, all in thermal equilibrium with photons. Tau neutrinos are already decoupled, previously coupled via electroweak. Hadrons are composite structures with finite dimensions, made of quarks, antiquarks and gluons. They are divided into three classes: baryons (three quarks bound together, qqq), antibaryons (three antiquarks bound together, $\overline{qqq}$) and mesons (a quark and an antiquark, $q\overline{q}$). Note that hadrons composed of more than three valence quarks may exist (tetraquarks, pentaquarks and hexaquarks).
All baryons, except the proton, are unstable and will decay. Figures 6 and 7 show some baryon families [41, 63, 64].

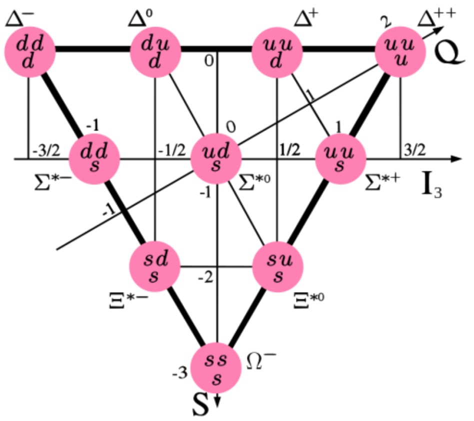

Figure 6. Combinations of three u, d or s quarks forming baryons with a spin -3/2 form the uds baryon decuplet [63].

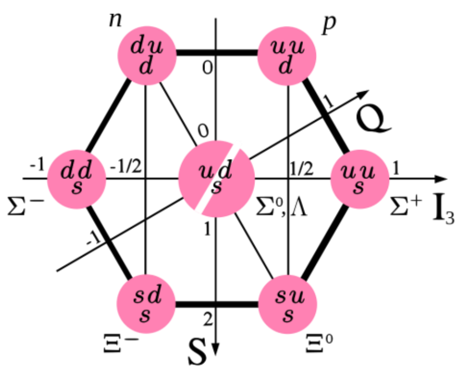

Figure 6. Combinations of three u, d or s quarks forming baryons with a spin -1/2 form the uds baryon octet [64].

All mesons are unstable, with the longest-lived lasting for only a few hundredths of a microsecond. Figures 7 and 8 show some meson families [65, 66].

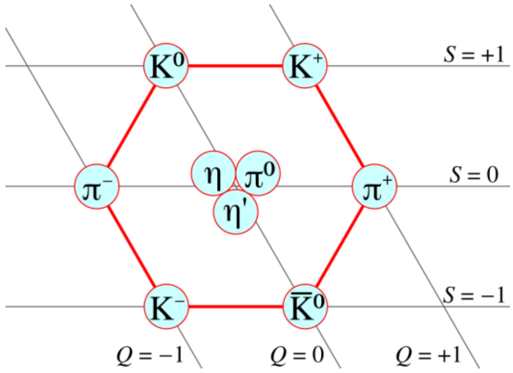

Figure 7. Combinations of one u, d or s quarks and one u, d, or s antiquark in $J^P = 0^-$ configuration forming a nonet [65].

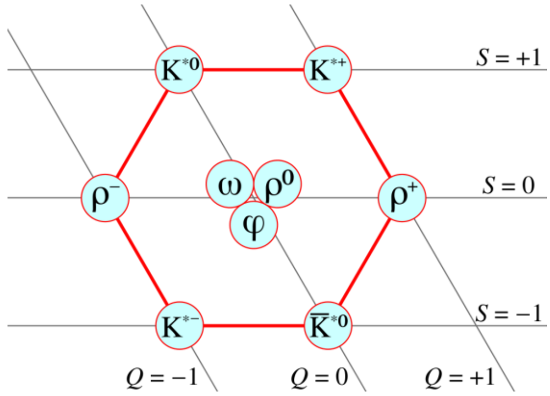

Figure 8. Combinations of one u, d or s quarks and one u, d, or s antiquark in $J^P = 1^-$ configuration forming a nonet [66].

At the end of this epoch we may define level 5 and class S_5:
S_5=
$$\{2 \text{ photons, } 8 \text{ gluons, } 12 \text{ leptons and antileptons, baryons, mesons}\}$$

6. Neutrino decoupling [67-69]
At approximately 1 second after the BIBA neutrinos decouple and begin travelling freely through space. This is the epoch at which neutrinos ceased interacting with other types of matter, and thereby ceased influencing the dynamics of the universe (radiation temperature 1 MeV). Neutrinos are still present today with about 56 electron neutrinos, 56 electron anti-neutrinos, 56 muon neutrinos, etc., per cubic centimeter, for a total of 337 neutrinos per cubic centimeter in the Universe.
7. Lepton epoch [61, 70, 71]
This epoch lasts between 1 second and 10 seconds after the BIBA (radiation temperature 1 MeV ~ 100 keV). By now, all hadrons and anti-hadrons from the previous epoch have annihilated each other, leaving the Universe full of leptons (electrons, positrons, some neutrinos) and antileptons. These particles then collide and annihilate each other resulting in energy being released as photons, leaving a small amount of leptons and no antileptons.
Big Bang nucleosynthesis [30, 42, 61, 72, 73]
This epoch lasts between 2 minutes and 20 minutes after the BIBA. The temperature has dropped to one billion degrees (radiation temperature 100 keV ~ 1 keV). This allows for nuclear fusion to take place and approximately 25% of the protons and all the neutrons fuse to form deuterium. Most of the deuterium rapidly fuses to form He-4. Summarizing, the only stable nuclides created by the end of BIBA nucleosynthesis are protium (single proton/hydrogen

nucleus), deuterium, He-3, He-4 and Li-7. Other stable isotopes produced are Li-6, Be-9, B-11, carbon, nitrogen and oxygen, but these are negligible. Note that nucleosynthesis occurred during the first few minutes of the photon epoch (below). This level is composed mainly by atomic nuclei.

8. Photon epoch [61]

This epoch begins at 10 seconds after the BIBA and lasts for 370,000 years (radiation temperature 100 keV ~ 0.4 eV). Most of the mass-energy in the universe is left in the form of photons. They continue to interact frequently with charged particles, i.e., electrons, protons and nuclei.

9. Recombination [61]

Recombination occurred about 370,000 years after the BIBA. This period lasted around 60,000 years and, by now, the Universe has cooled to only 3,000 degrees (radiation temperature 0.4 eV). The atomic nuclei now combine with the free electrons to form the elements hydrogen, helium and lithium. At this moment helium hydride (HHe^+) is formed. This is the first molecular ion formed in the Universe and thus the first chemical bond [74] (about 100,000 years after the BIBA). This action neutralizes the electrons' electric charge, which, in turn, frees the photons of light. This means that these photons should be now detectable by apparatus on Earth (called the cosmic microwave background). This level contains the first molecule-ion and the remains of previous epochs.

We shall stop our analysis at this point. The problems related to the ordering and classification of more complex objects will be left for the future. We observe that, the cooler the Universe gets, the more complex elementary particles are allowed to form. Also, elementary particles combine to form various kinds of new particles. During the recombination epoch free quarks exist no more. This way to analyze the appearance of the many particles and forces is appealing, but I feel that when we approach the time were more complex structures are formed (galaxies, solar systems, planets, planets with water, molecules that can 'reproduce', etc.), the level model presented here will fail. If we consider hadrons as being produced by fusion we may state that the first products of clustering are the atomic nuclei, followed by the HHe^+ molecular ion. Both can be considered to be the first systems. It is clear that the evolution of the Universe is associated with the appearance of more and more complex systems. It is important to mention that the levels just suggested do not comply with one of the main rules mentioned above since an object can belong to two or more levels (photons for example).

VIII. THE TIME-INDEPENDENT (STATIC) STRUCTURE OF LEVELS

This approach consists in create a first level containing all known elementary particles and from there to proceed building levels containing more complex objects.

1. Level one (L_1). The fundamental particles

Table 9 shows a partial table of fundamental particles within the Standard Model.

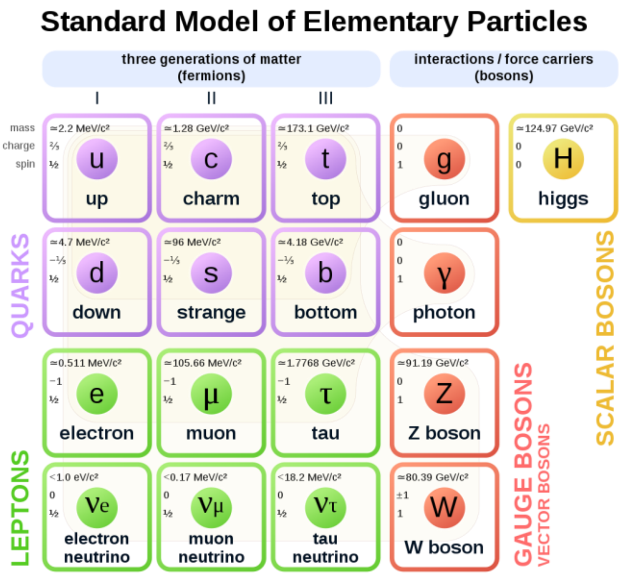

Figure 9. Incomplete Table of elementary particles [74, 75] (antiparticles and quark color are not included).

In Figure 9 there are 6 quarks, 6 leptons, 4 gauge bosons and one scalar meson. Now let us remember that there are six quarks but each comes in three "colors" making 18 particles and each has an antiparticle making 36 quarks in total (I made a mixture with quantum chromodynamics). Also, we have 12 leptons (antileptons included), eight types of gluons, the photon (γ, one or two types), two W bosons (W^+ and W^-), the Z boson (Z) and the Higgs boson (H^0). Therefore, this level comprises a grand total of 61 (or 62) elementary particles.

2. Level two (L_2). Hadrons.

Here we shall place all the combinations of the members of L_1. Therefore, this level includes all hadrons (baryons, exotic baryons, antibaryons, mesons, exotic mesons, antimesons, etc.). For practical reasons I will define three parallel levels: L_{2a}, containing the proton, L_{2b}, containing the neutron and L_{2c}, containing the remaining hadrons. I made this separation only because the free proton is stable and free neutrons are unstable, having a mean lifetime of about 14 minutes and 40 seconds. Also, onia are included (oniun corresponds to the bound state of a particle and its antiparticle, such as the positronium, pionium, protonium and kaonium). Note that some members of this level are produced by clustering (onia) and while other are produced by fusion.

3. Level three (L_3). Atomic nuclei.

The several thousand atomic nuclides belong to this level. Most of them are unstable. Also it includes the hypernuclei (a hypernucleus is a nucleus containing at least one hyperon, such as He-5-Lambda). As defined, this level meets the condition that all its members are formed only by members of level L_2.

4. Level four (L_4). Atoms and exotic atoms.

All atoms, isotopes included, belong to this level. An exotic atom (EA) is a bound or a quasi-stationary complex produced when a heavy negatively charged particle X (X= μ^-, π^-, K^-, Σ^-, $\overline{p}$,...) lands on a conventional atom [76]. Antihydrogen ($\overline{p}\, e^+$ [77]), muonium ($\mu^+ e^-$) are also classified as exotics atoms. All EAs belong also to L_4, together with ionized atoms keeping at least one electron. As we mentioned above, Oppenheim and Putnam suggested that "*anything belonging of any level except the lowest one can be decomposed into things belonging to the next lower level*"[18], while Feibleman stated that "*each level organizes the level or levels below plus one emergent quality* [property]"[28]. We can see that level four includes members formed by the clustering of members of levels L_3 and L_1. Therefore it seems that Feibleman suggestion fits with the model presented here. The emergent property corresponds to the chemical properties of L_4 members (emergent properties are properties of the "whole" that are not possessed by any of the individual parts making up that whole [78]). In this level the first systems (atoms) appear.

5. Level five (L_5). Isolated molecules and isolated exotic molecules.

A molecule is an electrically neutral group of two or more atoms held together by chemical bonds (zwitterions and Rydberg molecules included). The bond may result from the electrostatic force of attraction between oppositely charged ions (as in ionic bonds) or through the sharing of electrons (covalent bonds). This level includes also charged molecules (molecular ions), crystals, finite surfaces, etc. HeH^+ is included here. An exotic molecule contains one or more exotic atoms, such as positronium hydride (a positronium atom bound to a hydrogen atom) and di-positronium (two bound positronium atoms) [79]. Molecules that will be synthesized during or after the Recombination epoch are listed here also (as isolated systems) [80-82].

At this point we reach the same point than the time-dependent levels structure model. In level five of the time-independent model almost all structures are persistent in time (exotic molecules are exempted). The clustering of systems belonging to L_4 and the electrons from level L_1 is responsible for the formation of the systems of the systems listed on L_5.

The transit from L_4 to L_5 allows introducing the concept of 'emergency' and the exploration of another definition of complexity.

Emergence and complexity

In the book *Problems of Life and Mind* of George Henry Lewes the following comments related to 'emergence' are found [83]: "*The mistake here pointed out often arises from not discriminating between component parts and constituent elements"* (p. 90). "*The distinction here indicated between Components and Constituents, or between Parts and Elements, will be seen hereafter to have its importance. All quantitative relations are componental; all qualitative relations elemental. The combinations of the first issue in Resultants, which may be analytically displayed; the combinations of the other issue in Emergents, which cannot be seen in the elements, nor deduced from them*" (p. 90). In this context an Emergent is, for example, a water molecule produced by the combination of oxygen and hydrogen: *water emerges from them*. The link between level and emergence was presented by Edel with these words: "*Philosophically, the concept of levels involves the idea of some continuity of the new with the old* [here the *old* can be considered as level n and the *new* the level n+1 above it, J.S. G.-J.], *a maturing causal process which constitutes the emerging* [i.e., the 'things' of level n+1, J.S.G.-J.], *a field of novel or distinctive qualities with some order of its own (hence an element of discontinuity with the past), some degree of alteration in the total scene and its modes of operation because of the presence of the new* [as far as I know, this last idea has never been explored]. *Methodologically, a new level requires new descriptive concepts and, many believe, new empirical laws, independent of those of the old level*" [84]. There are many definitions for complexity[85]. *In a first approach*, we shall accept that the degree of complexity of a level is the quantity of information required to describe it. If this is correct, then the fundamental properties serving to define a level (i.e., the *intension* of the level) plus the necessary information to confer distinctness between members of the level could be employed to generate a quantitative measure of complexity. On the other hand, it seems that after a certain level (L_3) all higher levels are formed by the clustering of objects of lower levels. Note that our suggestion about the existence of level 1 is a practical denial of the thesis holding that each object is composed of more fundamental objects *ad infinitum*. If this is really true or is only the result of what actual physics theories describe is a problem out of the scope of this essay. Also, the view holding that particles are experimental phenomena rather than fundamental entities will not be analyzed for the moment [86]. I think that the experimental evidence of entities that can be described as 'particles' indicates, in one way or another, that there is an entity having extramental existence. Further developments of these models are under way.

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