Natural Systems and State Spaces

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Abstract

A schema is proposed assuming eight levels of reality, characterized by natural systems and the state spaces generated by the systems. Six of eight levels in this schema serve as sources of analogies, two levels are the targets of analogical reasoning. The source domains are the atomic, molecular, macromolecular, micro-organismic, organismic and socio-cultural systems and processes.

One of the target domains discussed in the article is the level of subatomic particles. The other target domain, not discussed in the article, could be the level of future supra-national systems.

A dual-space picture of natural systems can be defined, such that each system exists as point – like entity ('compound') in a 'common space' and at the same time as composite entity (composite of 'units') in an individual 'eigenspace'. The common space is populated by other systems of the same level, whereas the individual eigenspace contains only the parts (units) of a single system (compound).

The development of natural systems within a certain level and the emergence of a new, higher level represent two directions of evolution. A general term of the evolution is developed and the laws of system development are formulated as text and in symbolic form.

At the subatomic level, spacetime is identified as part of the state space of the subatomic particles. Spacetime is complemented by an eigenspace of subatomic particles, fixed to the structure of each individual particle. A "basic space" is proposed as the sum of all eigenspaces of particles. Subatomic particles exist simultaneously in space-time and in the circular basic space. Masses and charges circulate in basic space force-free and generate "intrinsic" properties such as the spin and magnetic moment of particles.

Analogical reasoning is used to obtain conclusions on a target level using generalizations of statements on the source levels. Logical operators and quantifiers are used for formalization.

A conjecture about the existence of hypothetical matter that is not detectable in space-time is derived. Such forms of matter could exist exclusively in the basic space and represent dark matter and dark energy.

Contents

1 Introduction

Analogical arguments have been used by philosophers since Aristotle and analogical reasoning are of philosophical and general interest in contemporary sciences [64]. Analogies based on similarities between natural systems are used, for instance, in biology, where the function of an organism to fly can be realized by birds, bats, and flying insects, developing analogical structures such as wings.

In a more abstract sense, one can compare at different levels the relationships between complex systems and their constituents. An organism as a whole consists of a large number of interacting cells, and each cell consists of a large number of interacting macromolecules. The question is whether there are similarities between different levels in such whole-part relationships. We should ask this question not only in the field of biology and microbiology but also in all branches of science: physics, chemistry, biology, and history of human communities.

The systems investigated by these sciences exist at different levels of structural organization and represent the result of completely different phases of evolution. The intention to formulate similarities between these different levels seems presumptuous and somewhat unusual.

However, in addition to the whole - parts–relations, there exist systemic properties at all levels and in all sciences, that can be compared. The most important properties are the relative indivisibility of systems acting as "building stones" of more complex structures and the adaptability of complex structures to their environment.

The term "evolution" has not a unique meaning. Evolution was originally used for the development of living matter only, and was connected with the systematics of protozoans, plants, and animals. This specific meaning of "evolution" is widely used also by contemporary authors [17][18][19][20][21][16]. Additionally, the development of galaxies, parts of the cosmos, or of the universe as a whole can be designated as evolution. The same is true for the development of minerals and geological formations as well as other parts of the inanimate world [3][6][7][8][9][10][27][37][41]. In addition, even immaterial objects such as languages or computer programs show evolution.

Investigations of evolutionary processes have been performed using mathematical methods, for example, by comparison with the self-similarity of fractals [25] or by other methods describing self-organization and complexity [42][44][45]. The most general point of view is the combined investigation of evolutionary development in living and nonliving systems [1][2][36][39][43].

The definition of evolution used in this study comprises not only the development of subatomic, atomic, molecular, and macromolecular systems. The living world also includes the development of viruses and bacteria, plants and animals, and human societies. Thus the term "natural system" is used with a very broad meaning in contrast to the different more specific definitions of this term in history [46].

The term "development" means conservation processes (steady state), modification (e.g. adaptation to external influences) and transformation (e.g. synthesis or decomposition and decay) of a system.

These types of processes will be considered in more detail in the next section.

The term "evolution" implies a certain relation to the sciences, which investigate the different material systems. One can emphasize the "unity of science" or the "diversity of the sciences". Sometimes the claim of a "unity of science" is connected with a reduction of all sciences into one scientific branch; e.g. one could prefer a more physical, a more biological or a psychological thinking and vocabulary. [34][35][38].

A reconciliation of the two interpretations of science–its unity or disunity–seems to be reasonable. We accept the diversity of different branches of physics, chemistry, biology, and human history. They use different methods and languages to present their results. However, we recognize the philosophical effort to extract common rules, similarities, and analogies between the results of these sciences. This constitutes an aspect of the unity of science in a more abstract sense.

The ‘unification’ or better generalization of selected scientific results also requires a generalized language, which allows the formulation of definitions and results applicable in physics, chemistry, biology, and history simultaneously. Such languages have been developed in different branches of philosophy [29][30][31][32][28]. Examples of terms belonging to a language applicable in general to natural systems are presented in the following sections.

2 The Evolution of Natural Systems

Levels of organization, periods of evolution

The reality was described by philosophers by dividing it into realms, layers, levels, strata or different material or mental “worlds”, back to the times of the antique Greece. However, the search for a classification of the real things and processes in accordance with the modern sciences began in the 20th century.

The “inorganic realm” in the ontology of Nicolai Hartmann ([69], 120) comprised 1949 the whole cosmos, including electrons, protons and neutrons as well as the atom, molecules and macromolecules up to objects of cosmic dimensions.

Oppenheim and Putnam [67] used 1958 a set of criteria for the identification of levels of organization, they found the following entities characterizing six levels: Social groups, (multicellular) living things, cells, molecules, atoms, and elementary particles.

The list of Oppenheim and Putnam needs a completion by macromolecules such as RNA, DNA and proteins, but otherwise it corresponds to the state of the sciences.

Wimsat [70] stated, that each level had a high probability of realization, if stable entities are available for the organization; he presented 1973 a drawing showing a sinusoidal "probability function" for the following levels: Atomic, molecular, macromolecular, unicellular, smaller metazoan, larger metazoan, socio-cultural / ecological [71].

Besides the entities, also their relations and the processes within them and interactions between them came into the focus of interest [68]. This was mainly influenced by recent developments in the interpretation of quantum mechanics, for instance the "relational quantum mechanics" proposed by Carlo Rovelli [54], based on the thinking of Werner Heisenberg [77][78].

The development of material systems seems to be directed into different branches, such as 'cell -> multicellular organism -> human' at the one hand, and 'animal -> hordes of animals -> fauna of a continent' at the other hand. Each of the branches could result in another scheme of levels.

Roberto Poli [65] emphasized the importance of clear definitions of the subject of ontological inquiry in defining levels. This appears necessary with respect to a plethora of different proposals which exists in literature; for a review see Blitz [72]. The development of generalized historical investigations under the headline of 'Big History' [66] provided a more historical oriented proposal of the time scale (called epochs, periods or levels) [79] [80] [81] [82].

The contemporary ontology has applications in many fields, such as linguistics, medicine, classification of knowledge [73], computer science and the management of "big data" [74].

This article deals with "natural systems", in a broad understanding of this term. For this purpose, the following five aspects have to be observed in defining levels of organization and of evolution:

1. Material systems (entities) including the structural relationships between them, such as whole – parts relations;
2. Chronological order of the evolution of systems, time – like and causal relations between evolving systems;
3. Processes that preserve, modify, create or destroy the systems including the interactions with the environment;
4. Space – like order of systems concerning geometrical and non-geometrical "state spaces", defined as the regions of reversible modifications of the systems, and

5. Branches (dimensions) of development characterized by a first dimension directed to the next higher level and a second dimension directed to an extension of the number of systems and their 'territory' within each level.

While the first three aspects are part of the theory of evolution and usually discussed in the ontological literature, the definition of state spaces for systems (aspect 4) is a new proposal. Recent developments of quantum gravity lead to the discussion of a non-spatiotemporal ontology [75][76]. Thus, it seems to be reasonable to consider comparable, abstract spaces at each level.

The existence of different directions of development (aspect 5) is well known, but the strict definition of a "two-dimensionality" of the development at each level is unusual.

Therefore, the aspects 4 and 5 will be discussed in more detail (see Sections 3 and 4).

Eight periods of evolution and eight levels of structural organization

In the first step, we divide the evolution into one of the non-living and one of the living worlds, finding the emergence of life as the only step in the development of matter. This exciting step has been the main research topic for decades and is far from complete understanding [4][26][12][13][14][15][40][16].

The differentiation in the evolution of non-living and living matter is doubtless the most important periodization.

Living systems have a limited life span, however, they show reproduction as a compensation. Despite this essential difference, living and nonliving systems have systemic similarities, and these similarities will be discussed in the following in detail.

The finer classification led to four periods of evolution. The development of living matter is divided by the emergence of human beings in a period of biological development below and a period of sociocultural development at the top of this event.

Similarly, the development of non-living matter is divided by the emergence of chemically active atoms. This essential step separates the physical world of particles, nuclei, and highly ionized ions from the world of the chemical reactions between molecules and macromolecules.

These four periods are separated by the emergence of the atom, living matter, and human beings. Nevertheless, four periods are not sufficient to identify the similarities of structures and processes; one requires an additional refinement of the classification. A scheme with eight periods of evolution or levels of organization is shown in Fig. 1[1]). This scheme can be justified by the emergence of a special type of systems called 'units' at each level, accompanied by the emergence of corresponding state spaces.

3 Levels of Reality, Units and Compounds

The emergence of units as building stones at each level

The division of evolution into periods is guided by the emergence of special types of natural systems (see Fig. 2).

Each of the eight levels is characterized by the existence of building stones of development, which are relatively indivisible and relatively stable; that means they are stable and indivisible with respect to a certain type of processes.

For instance, a human being is the building stone of sociocultural development in the history of mankind. A human organism can be destroyed, and it may die and decay. But for the special class of processes, which are essential for the development of social systems, the human being (in combination with its successors) is stable and indivisible, philosophically speaking an "atom". The same holds true for atoms in chemistry; they are stable and indivisible building stones of chemical development. This is true despite the fact that atoms can be completely ionized and their nuclei can be split or transformed by radioactive decay. However, such processes stop chemical development and represent another type of process.

[1]) The Fig. 1, 2 and 4 are translations from Figs. in [5].

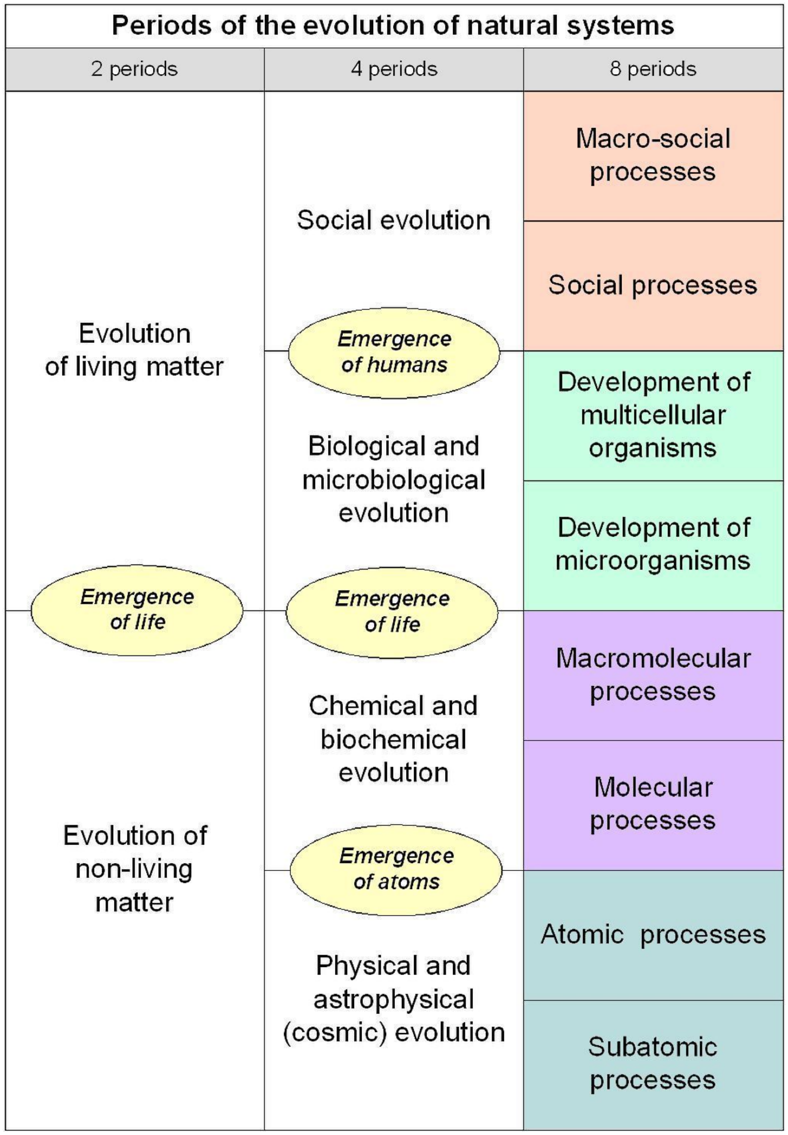

Figure 1: Historical periods and levels of organization in the evolution of natural systems. The last column shows eight levels, each level is characterized by newly emergent systems called “units”, see Figs. 2 and 3.

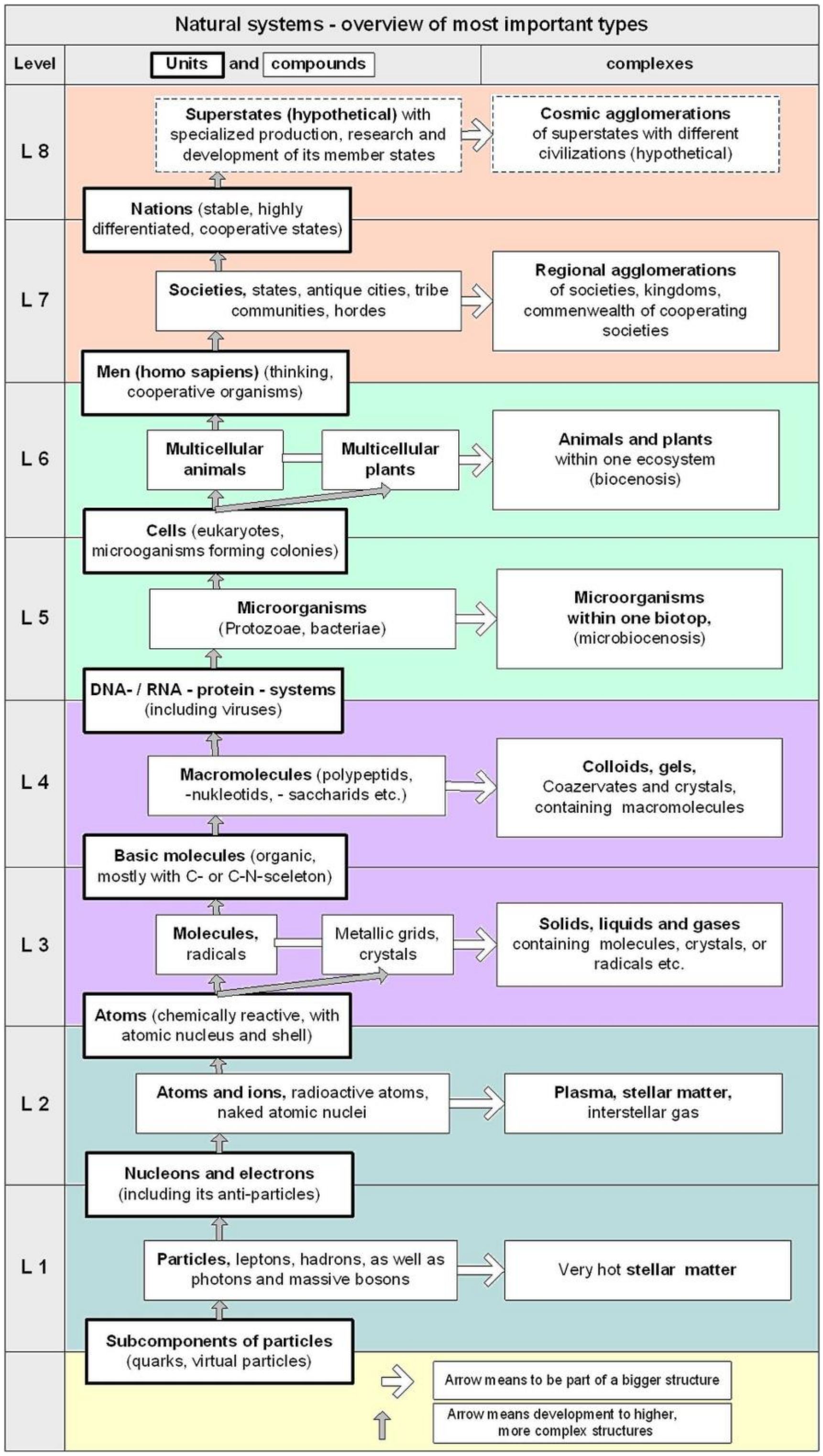

Figure 2: Types of natural systems in a "periodic table". The "units" mark the transition from level L(n) to L(n+1). Compounds of the level L(n), ready for transition, become building stones (units) of the level L(n+1). The emergence of units determines the occurrence of a new level.

Compounds as carriers of evolution

Two or more units form structures of different complexities, the development of which is the essential content of the evolution at this level. These evolution carriers are designated as ‘compounds’. For instance, tribe communities of Stone Age, antique city states, or modern nations are compounds of level L(7), with the human being as a unit. Molecules and radicals are compounds of level L(3), with chemical atoms as units.

An overview, a definition by enumeration, is shown in Fig. 3. The numbering of the levels used in this study is first given in Fig. 2.

n	Units U_n	Compounds C_n
8	Nations: stable, cooperative, highly differentiated social communities	Supranational and interplanetary organizations, cosmic civilizations
7	Human beings	Social communities
6	Cells	Organisms
5	DNA /RNA – protein systems	Micro-organisms
4	Monomer molecules	Macro-molecules
3	Atoms	Molecules and radicals
2	Neutron, proton, electron	Atoms and ions
1	Subcomponents of particles, rotons (Model assumption)	Particles (leptons, mesons, baryons, photons)
0		Free subcomponents: Mono-Rotons (hypothetical)

Fig. 3: Natural systems: A list of examples; a definition of units and compounds by (hitherto incomplete) enumeration. The source levels have green, the target levels yellow background. The level (0) is extrapolated and has purely hypothetic character (red background).

The compositeness of compounds can be expressed in symbolic form, see Fig. 4. We conclude by analogical reasoning from the source levels L(2)…L(7) to the target level L(1).

Compositeness of all compounds,
existence of subcomponents of particles

$$\forall C_n \hat{\supset} U_n \quad (n = 2 \ldots 7)$$
$$\Downarrow$$
$$\forall C_1 \hat{\supset} U_1$$

$\hat{\supset}$ Symbol of structural parthood

Fig. 4: Symbolic representation of the compositeness of compounds. The analogical reasoning starts at the source levels L(2) to L(7) and provides a conclusion for the target level L(1). Logical operators such as conjunction or disjunction and a few quantifiers are used like in the mathematical logic.

The formalization of the development of natural systems

Vertical development chain: simplification by omitting horizontal processes, see Fig. 5

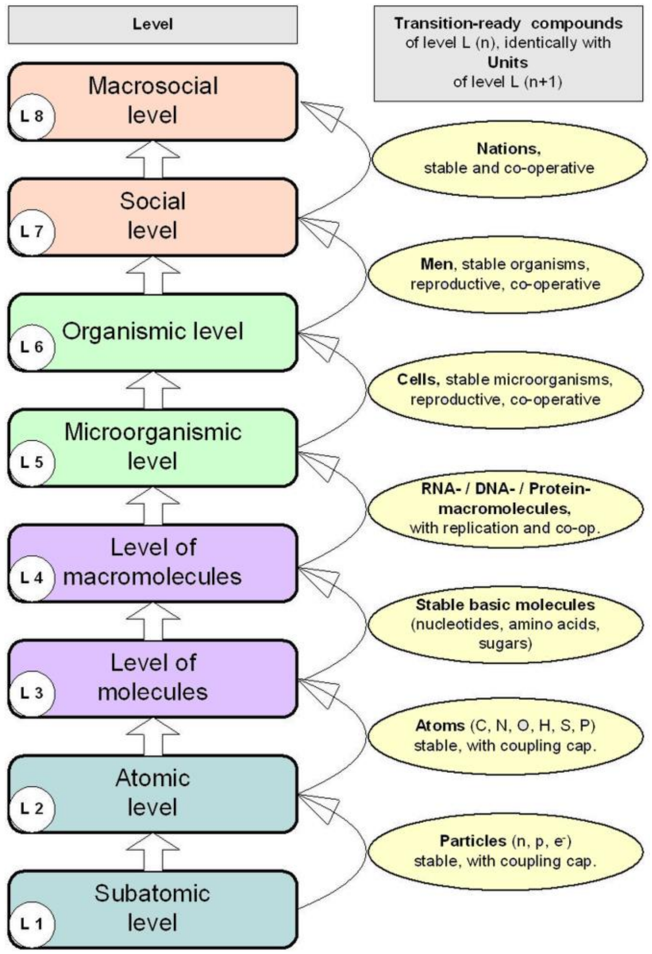

Fig. 5: The 'vertical branch' of evolution. The spatio-temporal extension of natural systems within a certain level is not shown.

Vertical development chain,
transition to the next higher level

$$\exists C_n \rightarrow \vec{C}_n \Rightarrow U_{n+1} \mathrel{\hat{\subset}} C_{n+1};$$
$$\exists C_{n+1} \rightarrow \vec{C}_{n+1} \Rightarrow U_{n+2} \mathrel{\hat{\subset}} C_{n+2}; \ldots$$

$\vec{C}_n$ Symbol of a compound ready for transition

$\Rightarrow$ Symbol of transition to the next higher level

$\hat{\subset}$ Symbol of structural parthood

Fig. 6: Symbolic representation of the vertical development chain. Existential quantifiers and logical operators are used like in the mathematical logic.

A complete representation is given in form of a general term (Fig. 7), where we set the level number n = 1 to 7. So the schema depicted in Figs. 7 and 8 is applicable between n -1 = 0 and n +1 = 8.

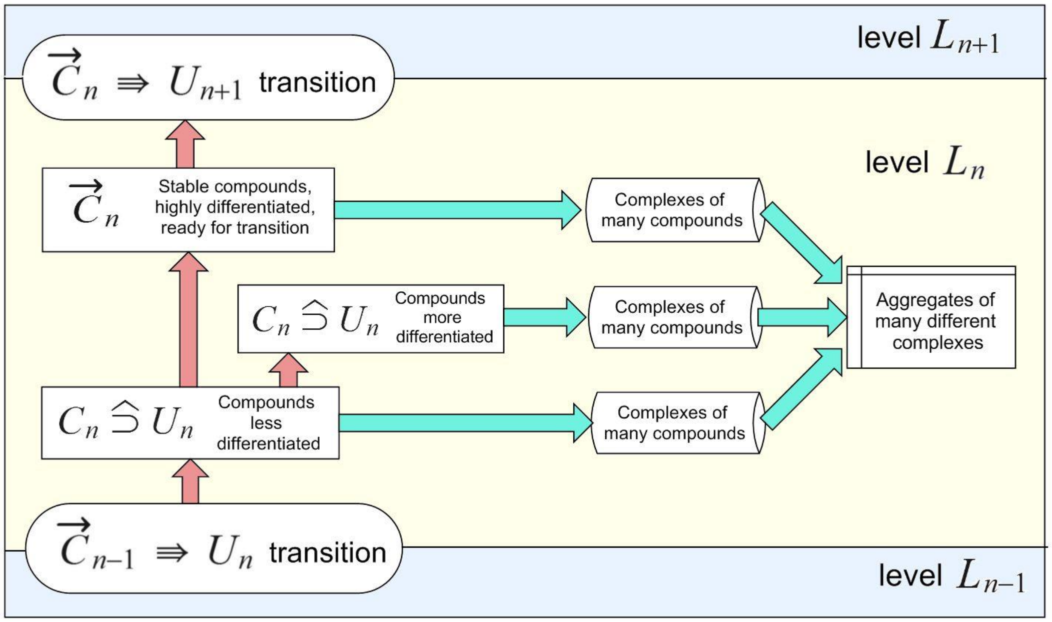

Figure 7: The 'general term' of structural relations between natural systems at level L(n). Evolution appears in two dimensions. In vertical direction, compounds with a higher complexity emerge and become units of the next higher level. In horizontal direction, the development leads to quantitative growth and spatiotemporal expansion of complexes and even more aggregated systems. The level number n has an upper and a lower limit, probably we have to set n = 1 to 7. By this way, we avoid the cases n – 1 < 0 and n + 1 > 8 which would have no meaning.

Compounds can be at different states of vertical development. The highest state is reached near to the transition to the next higher level. This special state of compounds is marked by an arrow:

$$\vec{C}_{n-1} \ : \vec{C}_n \ : \ \vec{C}_{n+1}$$

These symbols are used to symbolize this state of compounds of a certain level n-1, n or n+1 before the transition to the next higher level. A schematic view of the structural relations at level n, that is, the whole – parts relations, is given in Fig. 7.

The compounds $\vec{C}_n$ have a clear position within the development chain as indicators of a coming transition, see Fig. 8. During the transition, we use compounds with a double arrow as entities not only ready for transition, but already identically with the units of the next higher level:

$$\overleftrightarrow{C}_{n-1} \equiv U_n \ ; \overleftrightarrow{C}_n \equiv U_{n+1}$$

Using this notation, one can complement the schema in Fig. 7 with a short-form representation of the vertical branch of evolution, the ‘key component chain’, see Fig. 8. The key-component chain can be used for the top-down analysis of organizational structures, i.e. for determining the correct level of a given natural system.

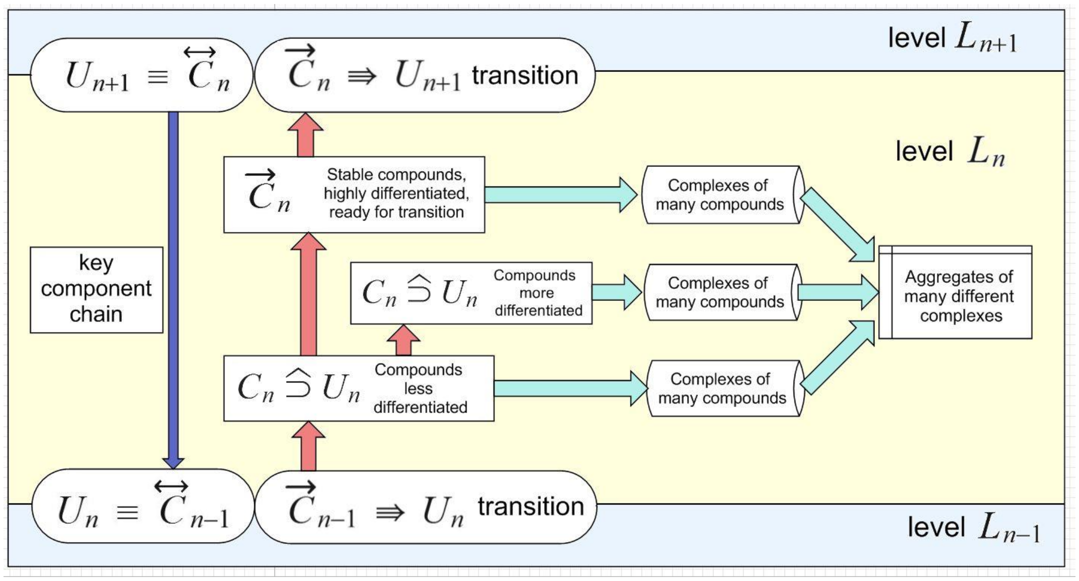

Fig. 8: General term of the evolution of natural systems within, below and above the nth level of reality. The level number n has an upper and a lower limit, probably we have to set n = 1 to 7. We avoid the cases $n - 1 < 0$, and $n + 1 > 8$.

The differentiation of the evolution in levels (see Fig. 2) is mainly determined by the existence of units. Units are the result of the transition processes. They emerge from the next deeper level through the development of compounds with a high degree of stability and functional differentiation. The emergence of such ‘compounds ready for transition’ has played a key role in all periods of evolution.

Each transition generates a new kind of ‘atoms’, the units; they become constituents of the compounds at the next higher structural level.

The special role of the units at each level does not provide an argument for "universal atomism". Each level has its own interconnection between the atomistic and holistic interpretations. Moreover, the term “atomism" has specific definitions in different branches of science, and misinterpretations are likely if it is used without explanation. Therefore, we avoid the term atomism in the following.

Compounds organize themselves in higher-order structures, designated as ‘complexes’, refer to Figs. 2, 4, and 6. Complexes may be organized in structural hierarchies of their own; this constitutes an additional dimension of development. However, this will not be addressed in this article. The focus of this article is on compounds and their structural and dynamic similarities.

From the subatomic to a ‚subparticle’ level

Physics at the subatomic level presents the most complicated situation.

Leptons and quarks are considered to be point-like; this is demonstrated experimentally by scattering experiments with electrons down to a distance of ~ 10^{-18} m. Theories assuming an extension in space-time must assume extremely small dimensions. Moreover, the search for a composition of leptons and quarks was unsuccessful [33][62]. This implies that they appear as ‘elementary’ particles. The experimental limits for the eventual existing but undetected constituents of elementary particles amount to very high energies of more than ~10 TeV. Thus, the energy of the ‘constituents’ of the particles exceeds the energy of the whole particle by more than three orders of magnitude. Even if we accept that leptons and quarks are point-like and elementary, fundamental problems still remain[2]).

The particles may appear as corpuscles in a detector or in the case of a collision, but they seem to propagate in space-time following a ‘matter wave’. This can be described mathematically by a quantum mechanical wave function or wave packet [57]. However, no carrier of the wave, field, or medium can be found experimentally by performing a wavy movement. It is not clear which kind of reality describes a wave function, wave packet, or superposition of different wave functions. Several interpretations of quantum mechanics exist [63][48][49][50][51][52][53][54] [55]; however, the ontological problem of the wave function has been discussed for approximately 90 years [47][56].

4 The State Spaces of Units and Compounds

Types of processes

The classification of systems has to be completed by a classification of processes. The entities and their relations, their behavior, is an essential subject of ontological studies.

Different types of processes preserve the current structure of a compound or result in structural changes with different extents. In general, the processes of conservation, modification, and transformation can be observed in the compounds.

Conservation refers to processes that guarantee stability in the steady state of the system. Conservation processes are characterized by an internal equilibrium between contradictory forces such as attraction and repulsion, bonding, and anti-bonding. The mechanisms of these forces depend on the level of evolution. Some kind of material, energetic, and informational exchange between the units of a compound usually represents the

[2]) Problems connected with "intrinsic" properties of point-like particles like spin or magnetic dipole moment are not mentioned, because they are not of primary importance for the discussion of the possible compositeness of the particles.

conservation processes. Concerning living systems, we focus on the conservation processes between two reproduction phases. In this respect a characteristic and essential part of the conservation of living systems is excluded from the comparative investigations performed in this article.

Modification processes involve the adaptation of compounds to alterations in the external or internal environments. Modification processes are reversible excitations that do not fundamentally change the structure of the compound. A modification process generates transitions between different conservation processes, that is, between different states of the internal equilibrium of the compound.

Transformation is the term for severe alterations, the synthesis of new structures, and the destruction or decay of old ones. Transformations are engines of evolutionary development. A comparative study of transformations was not performed, it would need a separate article.

The common state space of compounds and the region of adaptation

Working with the definition of abstract state spaces, configuration spaces, or phase spaces is common practice in many branches of science.

Such a definition makes sense, for example, when transitions between states can be treated as 'motion in the state space' more clearly or mathematically precise than without this concept.

Modification processes of compounds should not lead to transformations. This condition is fulfilled if the modification does not exceed a certain limit. Such a limit defines the "adaptation region" of the compound. The totality of equilibrium states within the adaptation region spans the 'common state space' of the compound.

A common space emerges simultaneously with compounds at a certain level of evolution. A common space cannot be defined without the existence of compounds, which 'span' this space.

Each 'point' in the common state space corresponds to exactly one state, i.e. a certain strength of bonding and anti-bonding of the units within the compound. A compound always has a certain state; therefore, it necessarily exists at one point in the common state space. Interactions between different compounds can be interpreted as collisions in the common state space.

The motion of a compound from state A to state B within the common space is performed without changes of the units. The units have during such a motion the role of 'atoms', they appear as indivisible and unchangeable building stones.

The eigenspace

The internal state of a compound is essentially determined by the functional differentiation of the units, the constituents of the compound. Units are themselves composite systems and have a spectrum of states. The spectrum of a special unit depends on the function of this unit within the compound. The entirety of states of all units forming a compound establishes the ‘eigenspace’ of that compound[3]). The compound appears always as ‘extended’ in its eigenspace, because it occupies different states at the same time, depending on the number of units and the degree of their differentiation.

Examples of common spaces and eigenspaces at different levels are given in Fig. 9. The lists in Fig. 9 represent definitions of the state spaces by enumeration. However, these lists are preliminary and partly incomplete.

n	Common spaces S_n	Eigenspaces E_n
7	Behavioural states of social communities	Internal states (education, health care)
6	Behavioural states of organisms	Internal states (nervous syst., hormones)
5	Behavioural states of micro-organisms	Internal states (gene expression, energy prod.)
4	Collision types of macro-molecules	Internal conformation and activation states
3	Rotational-vibrational states of molecules	Internal electronic excitation, H – H coupling
2	Excitation states of atoms, ions, nuclei	Internal shell states of electrons and nucleons
1	Dynamic states of particles colliding in space-time	Internal states of composited particles (binding energy)
0	States of gravitational interaction beween free subparticles (mono-rotons, hypothetical)	

Fig. 9: State spaces: A list of examples; a definition of common spaces and eigenspaces by (hitherto incomplete) enumeration. The source levels have green, the target levels yellow background colors. The level L(0) is extrapolated and has purely hypothetic character (red background).

A compound exists simultaneously in two spaces, the external ‘common space’ and the internal, structure-fixed ‘eigenspace’. The symbolic representation of this ‘dual space concept’ is presented in Fig. 10.

The first line in Fig. 10 (with yellow background color) contains a general statement on the relation of natural systems and their state spaces in the source levels L(2) to L(7). The first line shows on the left side the statement on the inclusion of a compound in the common space, characterized by one position or one state at an instant in time (we call it non-extended). On the right side, the first line shows the inclusion of a compound in the eigenspace, where the compound has different states at the same time (we call it extended).

The second line in Fig. 10 (with yellow background color) shows the same two statements for a compound at level L(1), derived by analogical thinking from the first line. We emphasize the right side of the second line,

[3]) The terminology for state spaces was different in previous versions of this article: the common space was designated ‘upper state space’, the eigenspace had the name ‘lower state space’.

because the eigenspace E(1) is not an established physical fact, but a kind of prediction. It means the existence of an internal state space of particles, the eigenspace, taken away together with the particle.

The dual space concept for compounds, spatial extension of particles in its eigenspace

$$
\begin{array}{ccc}
\forall C_n \overset{\bullet}{\in} S_n & \wedge & \forall C_n \overset{\star}{\in} E_n \quad (n = 2\ldots7) \\
\Downarrow & & \Downarrow \\
\forall C_1 \overset{\bullet}{\in} S_1 & \wedge & \forall C_1 \overset{\star}{\in} E_1
\end{array}
$$

$\overset{\bullet}{\in}$ Symbol of non-extended inclusion in a space

$\overset{\star}{\in}$ Symbol of extended inclusion in a space

Fig. 10: Symbolic representation of the dual space concept for compounds. The analogical reasoning starts at the source levels L(2) to L(7) and provides a conclusion for the target level L(1). Logical operators such as conjunction or disjunction and a few quantifiers are used like in the mathematical logic. The ‘extended inclusion’ in a space means the occurrence of different states at each moment of time – quite normal if different subsystems exist and their states are relevant for the whole.

The eigenspace of a particle resembles the space of a spinning top or a drone, spanned by its body-fixed coordinates, see Fig. 11.

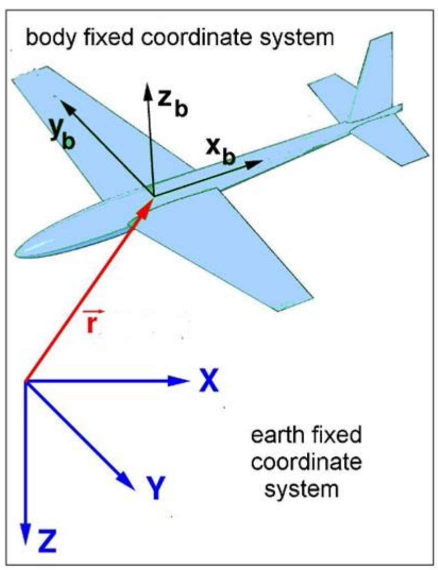

Fig. 11: The body-fixed coordinate system of a drone spans a space, which resembles the eigenspace of a particle. However, the eigenspace of a particle is not embedded in spacetime.

The existence or non-existence of units within a state space

Existence or non-existence in a certain state space is an important property of a system. Units do not exist in the common state space of compounds of the same level. This is shown for the source levels (2) to (7) in Fig. 12.

n	Unit U_n	Non-existence of an U_n in the common state space S_n
7	Organism, single human being	A single organism does not have economic or socio-cultural states comparable to that of a social community, but it may exist as part of such a system
6	Micro-organism, single cell	A single cell does not have neurologic or metabolic states comparable to that of an organism, but it may exist as part of such an organism
5	Macro-molecule, Single DNA/RNA-protein system	A single macro-molecule does not have metabolic states comparable to that of an micro-organism, but it may exist as part of such a micro-organism
4	Molecule or radical, Single monomer	A single monomer-molecule does not have states of conformation, comparable to that of a macro-molecule, but it may exist wthin a macro-molecule
3	Atom or ion	A single atom does not have states of vibration or rotation, comparable to that of a molecule, but it may exist as a part of a molecule
2	Stable or unstable particle, single p, n or electron	A single particle does not have states of electronic or nuclear excitation, comparable to that of an atom or ion, but it may exist as a part of an atom
1	Subcomponents of particles, rotons	A single roton does not have translational states comparable to that of a particle, but it may exist as a part of a particle

Fig. 12: Single units do not exist in common spaces: List of examples. The source levels have green, the target level L(1) has yellow background colors.

Units exist in the Eigenspace, but they are non-existent in the common space of the compounds, to which they belong. The symbolic representation is given in Fig. 13.

Existence of units in its eigenspace,
Non-existence in the common space of that level

$$(\forall U_n)_{n=2}^{n=7}, \quad U_n \overset{\bullet}{\in} E_n \;\wedge\; U_n \overset{\bullet}{\notin} S_n$$
$$\Downarrow$$
$$(\forall U_1), \quad U_1 \overset{\bullet}{\in} E_1 \;\wedge\; \boxed{U_1 \overset{\bullet}{\notin} S_1}$$

$\overset{\bullet}{\in}$ Existence in a state space
as non-extended object (in one state at a certain time)
$\overset{\bullet}{\notin}$ Non-existence in a state space

Fig. 13: Symbolic representation of the non-existence of single units in the common space of compounds. The analogical reasoning starts at the source levels L(2) to L(7) and provides a conclusion for the target level L(1). By analogical thinking follows, that the units of L(1), the subcomponents of particles, do not exist in spacetime, the common space of particles. This important, but unusual conclusion has a red frame.

By analogical reasoning follows for the target level L(1), that units of that level, namely the subcomponents of particles, do not exist in spacetime. This conclusion depends on two facts:

1. Spacetime represents at level L(1) also the state space of translational states of particles.
2. Single, unbound rotons (no longer subcomponents of particles) doesn’t have translational states and coordinates in space-time.

Spacetime has at different levels a special appearance, in particular at level L(1). The common space S(1) is a geometric space defined by a metric and as well a state space defined by translational states of particles [83]. This complex character of spacetime S(1) will be discussed further in section 6, see also Fig. 15.

If we consider a complex of several compounds instead of one compound, it is no longer point-like in the state space because, in general, not all compounds are in the same state. One can say that a complex has a certain ‘extension’ in the state space of the compounds. The larger the aggregates of complexes, the more space is occupied in the state space of the compounds.

The units, on the other hand, cannot exist in any of the equilibrium states of the compounds, they are ‘non-existent’ in the common state space. Examples at different levels of evolution are listed in Fig. 12.

5 The dual-space concept for compounds at different levels

Compounds at level L(n) have a dual nature, represented by properties belonging in part to the state space S(n) of level L(n) and partially to the state space S(n-1) of level L(n-1). The state space S(n-1) of the lower level becomes at level L(n) the eigenstate E(n) of the compounds.

Compounds show spatial duality, that is, they have a dual nature with respect to their state spaces. This will be discussed in more detail in the following.

The state spaces of social communities

Social communities of human beings, such as antique cities or modern states, represent the compounds at level L(7). In such communities, humankind shows differentiated and highly specialized material and intellectual production. Humans develop education, science, arts, and different forms of communication using languages and pictures. This has to be considered as the ‘common space’ $S(7)$ of the existence of communities, which cannot be achieved to the same extent by societies of animals.

However, the same communities need safe spaces to live and reproduce; they need food, drinking water, and other prerequisites of life. They can also suffer from endemic illnesses. This is called the ‘eigenspace’ E(7), which is similar to the state space of hordes of animals. Animals, like other multicellular organisms, are compounds at level L(6). This means that social communities of human beings show a dual existence at level L(7) as well as at level L(6). The eigenspace E(7) is the legacy of S(6).

The existence of social communities in its eigenspace is also preserved if movements in its common space are reduced or nearly absent (e.g., during complete lockdown in a pandemic situation). The eigenspace is spanned by the minimum or "static" properties of the community.

The state spaces of organisms – multicellular animals and plants

Multicellular organisms (plants and animals) represent compounds at level L(6). Organisms develop signal transfers between specialized cell groups. This can be realized through nervous, hormonal, chemical, or other types of communication. In this way, the organism, including other organisms, generates a coordinated reaction to its environment and other organisms. These properties span the 'common space' $S(6)$ of an animal or a plant.

On the other hand, the same organisms need a certain temperature range, energy source, and chemical environment (water within a certain pH range, ion content, and oxygen content). Organisms must supply certain conditions of life to their cells. This represents the 'eigenspace' $E(6)$ of organisms, which is similar to the needs of single-cell organisms, the compounds of level L(5). In many cases, the reproduction cycle of a multicellular organism contains a stadium of a single - cell existence, the zygote. This means that multicellular organisms show a dual existence at levels L(6) and L(5).

The existence of organisms in the eigenspace is also preserved if movements in the common space are reduced or completely absent (e.g., during sleep or unconsciousness). The eigenspace is spanned by the minimum or static properties of an organism.

The state spaces of micro-organisms and viruses

Micro-organisms, such as protozoans, bacteria, and viruses, represent compounds of level L(5). A virus exists near the borderline between non-living and living matters. If a virus is able to occupy the infrastructure of a host cell, it develops metabolism and shows different functions, such as interactions with the immune system of its host. These are characteristics of level L(5) and span the common space $S(5)$ of a virus or another microorganism.

In contrast, a virus behaves like an ensemble of macromolecules. A number of identical isolated viruses may be crystallized and characterized by X-ray spectroscopy, similar to other macromolecules, which are units of a virus. The macromolecular properties of a virus constitute its eigenspace $E(5)$. This state space of a virus is similar to that of a macromolecule, a compound at level L(4). Thus, viruses are the most prominent examples of systems with dual properties, which belong in part to level L(5) (animate matter) and in part to level L(4) (non-animate matter).

The existence of microorganisms and viruses in its eigenspace is also preserved if movements in the common space are reduced or absent (e.g., in states of low or nearly absent metabolic activity). The eigenspace was spanned by its minimum or 'static' properties.

The state spaces of macromolecules

Macromolecules, such as polypeptides, RNA, or DNA, represent compounds of level L(4). They are usually folded in three dimensions; this conformation results in the differentiation and specialization of single molecules, the units that constitute the macromolecule. The molecules as constituents of a polypeptide, for example, can be located at the surface, in holes, or in the interior of the macromolecule. These variants of (mostly biochemically active) conformations span the common space $\mathrm{S}(4)$ of the macromolecule. The sequences of nucleotides G, U, A, and C determine the structure of a DNA macromolecule. Its state space is defined by the totality of spiral-like structures or folding of the chain of molecules.

On the other hand, a macromolecule in any conformation has to react to external influences, such as high temperature, irradiation by photonic energy or acidic content. Similar to the reaction of single molecules, macromolecules may change their state of vibration and rotation. These are movements in its eigenspace $\mathrm{E}(4)$. The state space of molecular vibrations and rotations belongs to level L(3), where molecules represent the compounds. In general, macromolecules show a dual existence at levels L(4) and L(3).

The existence of macromolecules in the eigenspace is also preserved if movements in the common space are reduced or absent (e.g., frozen biochemical activity and stopped conformational changes at low temperatures). The eigenspace is spanned by the minimum or 'static' properties of a macromolecule.

The state spaces of molecules and radicals

Molecules such as amino acids, sugars, or water, and radicals of such molecules represent the compounds of level L(3); atoms with their capabilities to undergo chemical bonds are the units of that level. Molecules have a certain spectrum of rotational and vibrational states and the characteristics of L(3). This variety of states spans the common space $\mathrm{S}(3)$ of the molecules.

However, molecules may behave similar to atoms in a gas, absorb and emit photons with characteristic wave lengths. In such cases, these molecules and radicals behave like systems of level L(2); they move in its eigenspace $\mathrm{E}(3)$. The dual nature of molecules e.g. in a cosmic gaseous nebula is caused by the fact, that they show the newly emerged properties of level 3 (rotation, vibration) and also the old properties of level 2 (excitation in the electronic orbitals, emission of light with a characteristic spectrum, ionization). These 'old' properties of molecules are inherited from its constituents, the atoms.

The existence of molecules and radicals in the eigenspace is also preserved if movements in the common space are reduced or absent (e.g., in the ground state where rotations and vibrations are zero or nearly zero). The eigenspace is spanned by the minimum or 'static' properties of a molecule.

The state spaces of atoms and ions

Atoms, ions, and naked nuclei represent compounds at level L(2). Protons, neutrons, electrons, and photons are units of this level. The excitation of the atomic shell and even of the nucleus are the characteristics of that level, these excitation states span the common space $\mathrm{S}(2)$ of atoms and ions.

On the other hand, atoms, ions, and naked nuclei in the plasma may react similar to free particles. They change the direction of their translational movement and exchange kinetic energy during collisions with other particles, and the space-time at level L(1) is their eigenspace E(2). The existence of atoms and ions is spatially dual: they populate the state space of excitations of the shell and nucleus at level L(2), as well as the Minkowski space-time at level L(1).

The existence of atoms and ions in the eigenspace is also preserved if the movements in the common space are reduced or absent (e.g., in the ground state of the shell and nucleus, where no excitations occur). The eigenspace is spanned by the minimum or 'static' properties of atoms or ions.

The state spaces of leptons, hadrons and photons

Leptons, hadrons, and photons represent compounds at level L(1). Their dynamical behavior in space-time according to the Dirac equation and the Maxwell equations has to be interpreted as a movement in its 'common space' $S(1)$. Some properties of the particles, especially their spin, cannot be explained by such translational movements. There exist mathematical descriptions, but no classical correlates, no ontological explanation of spin, or magnetic dipole moment.

Particles and photons have no 'eigenspace', $\text{that means } \mathrm{E}(1)$ is *missing* within the established particle physics. The necessity to assume vacuum expectation values and the existence of virtual particles indicate, that something has to be added to the Minkowski' space-time. In addition, the 'intrinsic' character of the spin of point-like particles and photons shows a certain incompleteness in the usual picture of particles and photons.

In analogy to other levels we conclude, that the existence of particles in its eigenspace E(1) should be preserved also if movements in its common space S(1) are reduced or absent, e.g. if they are more or less 'at rest' in space-time. An approximation to such a state of rest is possible by an appropriate choice of a system of reference, at least for massive particles. The preserved static properties of such particles at rest are 'rest'-mass (derived from its invariant energy), spin and charge in case of charged particles.

Photons and neutrinos do not go with this picture; they require additional discussion. However, in all cases, the eigenspace $\mathrm{E}(1)$ is *missing*.

The basic space at the subparticle level

We can conclude that the dual existence of compounds at level L(n) in an common state space $S(n)$ and an eigenspace $\mathrm{E}(n)$ is a general property at the six levels L(2) to L(7). By analogical reasoning, this 'spatial duality' should also exist at level L(1).

We introduce the 'basic space' as $\mathrm{E}(1)$ to complete the dual character of leptons, hadrons, and photons, analogous to the dual character of compounds at the other levels[4]). Subatomic matter, especially fermions, can exist as point-like particles in space-time S(1) and simultaneously as extended objects in basic space. Early forms of matter could possibly exist in basic space only, not detectable as particles or waves in space-time. This proposal would have consequences for the particle models, the nature of dark matter and dark energy, and different cosmological problems.

In summary, we need four fields of information per level in order to describe the vertical development of natural systems, see Fig. 14.

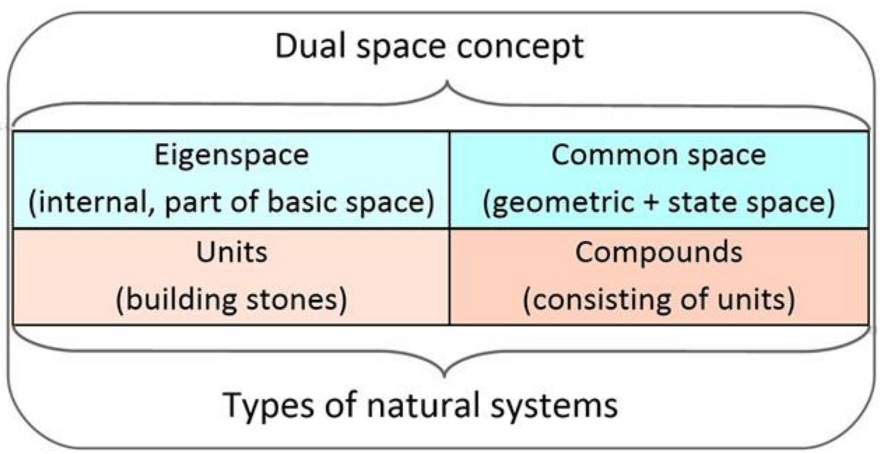

Fig. 14: Four fields of information per level of reality are needed to describe the vertical development of natural systems. However, these four fields of information are only sufficient in such cases, where processes in the subcomponents of units, i.e. the sub-subcomponents of compounds, are irrelevant.

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[4]) The assumption of a "basic space" as the state space of subatomic particles and its possible role in the early phases of the universe was 2016 introduced in a book on the "Analogies between Natural Systems on eight Levels of Evolution", p. 164 (in German, [5])

6 The Mixing of different Aspects in one Space

The existence of compounds in space-time has a geometric, territorial aspect and an aspect of duration. A compound has an extension in three dimensions and shows a motion through space and time. The sum of spatial extension, motion area and timely duration of the existence of a compound defines the geometric space-time area belonging to this compound. The combination of geometrical and non-geometrical aspects of space is schematically shown in Fig. 15.

		Level of structural organization								
	Level	L 0	L 1	L 2	L 3	L 4	L 5	L 6	L 7	L 8
Level of evolution	L 8		Outer space (galactic, extra-galactic)							SSM: Cosmic civ.
	L 7		Geographical space (territories of social communities)						SSM: Social commun.	
	L 6		Living space of plants and animals					SSM: Organisms		
	L 5		Living space of micro-organisms				SSM: Micro-organisms			
	L 4		Geometric space of macro-molecules			SSM: Macro-molecules				
	L 3		Geometric space of molecules		SSM: Molecules					
	L 2		Geometric space of atoms	SSM: Atoms, ions						
	L 1		Geometric space + SSM: Paricles							
	L 0	Basic space, SSM: Free rotons								

Fig. 15: State space models (SSM) exist in geometric spacetime (yellow background) and show in addition non-geometrical state space aspects (green background) at each level of reality. The two aspects of space are realized at once at the subatomic level L(1). The geometric aspect disappears at level L(0), but it remains the aspect as state space.

The role of compositeness of particles

Within the standard model of particles, all leptons and quarks are considered elementary particles without compositeness. The introduction of the proposed basic space would change this situation.

Any model of leptons, quarks, and photons with spatial duality would consist of two partner models: the usual model in space-time, for example, describing an elementary point-like lepton or fermion, and the basic space model, for example, representing a composited lepton or fermion as an object extended in the eigenspace. The intrinsic properties of particles, such as spin and magnetic dipole moment, can be described naturally in basic space if it is defined as a circular space. Such models with spatial duality are discussed in a separate article [83].

The connection of eigenspaces and particle structure

The common state space is connected to the structure of the compound. In general, there is no empty space, independent of the structure that generates the different states. This is especially true for such periods of evolution where compounds of higher levels do not yet exist. In the hot plasma, no molecules were formed. However, if corresponding cooling occurs, the first two or three atoms couple and build a molecule that performs rotations and vibrations. The state space of these rotational and vibrational states emerges from the first molecule. It does not exist in a hot plasma without molecules.

The common state space emerges only with the structure of the compound, whose states are the defining items of that space. The state space was structurally connected. This fact resembles the relations of body-connected coordinates of a satellite or a spinning top to these bodies: The coordinate spaces do not exist without the bodies.

7 Interactions between Systems at Level L(n) and at Level L(n-1)

If matter is ready for the transition to the next evolutionary level L(n), the newly developed compounds will interact, undergo modifications, and undergo transformations. In addition, the old interaction belonging to the next deeper level L(n-1) of the evolution will continue. The structures of level L(n-1) cannot populate level L(n), however they are effective by interacting with structures of level L(n).

A biological example is given by organisms such as plants and animals at level L(6). They are used to breed for food by human beings, organized in social communities of L(7). If animals or plants are used in agriculture, they belong to the common space S(7) of social communities (food production). Nevertheless, the single organism used in agriculture does not show the typical states of a social community (production, education, science, arts).

A next biological example is given by bacteria with at level L(5) can take advantage of protein molecules and even pieces of DNA in their environment, which become their constituents during metabolic processes. Such macro-molecules belong to level L(4).

An example from the inanimate world represents atoms of a hot gas that interact with photons and electrons in the environment. For additional examples refer to Fig. 16.

n	Level	Interaction of compounds at L(n) with systems of the the next lower level: C_n ←→ C_{n-1}
7	Social	Social communities ←→ Organisms such as animals and plants (interaction by hunting, farming, breeding) *Organisms do not exist in the common state space of social communities.*
6	Organismic	Animals and plants ←→ Micro-organisms (bacteria, protozoans, viruses) *Bacteria do not exist in the common state space of animals and plants.*
5	Micro-organismic	Bacteria, protozoans ←→ Free macro-molecules (DNA, RNA, polypeptides) *Free macro-molecules do not exist in the common (metabolic) state space of bacteria*
4	Macro-molecular	Macro-molecules ←→ Monomers (amino acids, sugars, water) *Free monomers do not exist in the common (conformation) state space of macro-molecules*
3	Molecular	Molecules and radicals ←→ Free atoms and ions *Free atoms and ions do not exist in the common (rotational-vibrational) state space of molecules*
2	Atomic	Atoms and ions ←→ Free particles (n, p, e, and photons) *Free particles and photons do not exist in the common state space of atoms (electronic + nuclear excitation)*
1	Subatomic	Particles and photons ←→ Free rotons, subcomponents of particles (interaction by gravity) *Free rotons (subcomponents of particles) do not exist in the common translational state space of particles (in space-time)*

Figure 16: Interaction of compounds at level (n) with systems at level (n-1). Isolated systems at the next lower level (n-1) cannot be localized in the common state space of systems at the higher level L(n). At the subatomic level L(1) the hidden character of dark matter and dark energy could be caused by free rotons (mono-rotons, not bound to particles).

8 Hypothetical matter existing exclusively in basic space

One can speculate that isolated subcomponents of particles exist exclusively in the basic space, not as a partner of a particle with spatial duality. This requires the assumption of the existence of level L(0). At this level L(0), the state space $S(0)$ would be populated by hypothetical primitive types of matter not capable of manifesting themselves and moving in space-time. Matter at this level represents probably the lower termination of the vertical whole-parts chain. The relations of the hypothetical level L(0) and the two higher levels L(1) and L(2) is shown in Fig. 17:

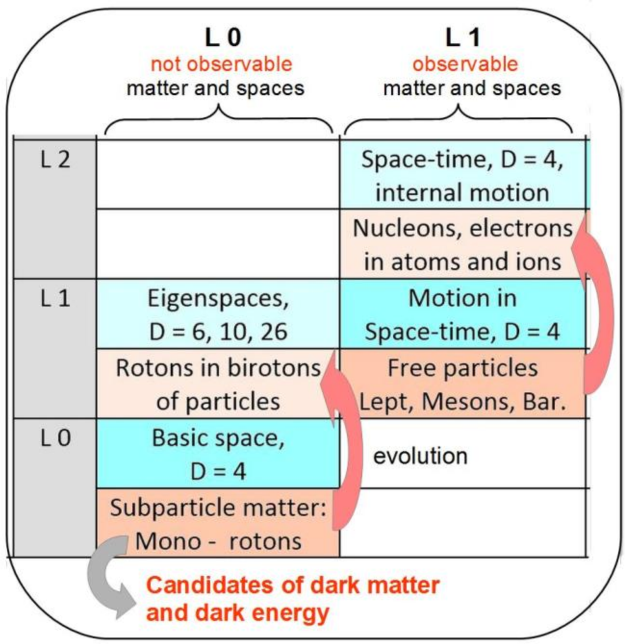

Fig. 17: The hypothetical subparticle level L(0) and its relations to the subatomic and the atomic levels. The four fields of information, already mentioned in Fig. 14, are depicted for the subatomic level L(1). Two of these four fields are observable (intense background colors), two are not directly observable (light colors).

The cosmic inflation and the emergence of space-time - together with particles

Let us discuss the conjecture that special forms of matter exist in basic space, without the ability to appear in space-time. In the early universe, all matter and all energy could be located in the basic space $S(0)$. Instead of a singularity in space-time, which contains all the matter with infinite density at the moment of the big bang, a wide distribution of non-particle, non-photon matter could have existed in basic space. Instead of an inflationary expansion, starting from the singularity in space-time, a large number of transitions of structures in basic space to point particles and photons in space-time could have taken place, with presumably nearly the same effect as with the cosmological inflation.

Each transition generates a particle or photon surrounded by an insular piece of space-time $\mathrm{S}(1)$, with its proper time as the time axis. Only a large number of such newly generated insular pieces would result in the development of a general space-time. The 'old' states of circulating matter in basic space are preserved by the transition of the corresponding state spaces: $\mathrm{S}(0) \Rightarrow \mathrm{E}(1)$.

This seems to be speculative and was not tested by observations or subsequent calculations. In particular, it should be determined whether the cosmic background radiation is in accordance with this possibility.

The presumption that space-time emerges in connection with the structure of particles was expressed by different authors [22][23].

Also the current research on quantum gravity goes in the direction of non-spatiotemporal theory [24]. It turns out that space-time is absent at the most fundamental level and emerges only in an appropriate limit [23]. This would possibly allow the development of a variant of quantum gravity on a level below space-time, chronologically before the emergence of space-time.

Dark matter and gravity

Dark matter and dark energy could be a consequence of the existence of matter, which is not able to appear and to move in space-time. Nevertheless, such forms of matter could interact with matter in space and time by means of gravitation. This would be a model explanation for the fact, that no candidate could be found that represents the content of dark matter or dark energy in space-time.

This conjecture would require that the gravitational mass as a source of gravity is already present at level L(0).

If this interpretation of dark matter and dark energy could be demonstrated to be correct (such that this idea would become a part of a consistent theory), then the gravitational effect seen in the movement of galaxies would be the only sign of the existence of dark matter forever.

In the same context, also the search for a theory of everything would be questionable. At the one hand gravitation would represent the main characteristics of matter in the state spaces $\mathrm{S}(0) \Rightarrow \mathrm{E}(1)$. At the other hand, the electromagnetic, weak and strong interactions would represent the characteristics of the higher level state spaces $\mathrm{S}(1) \Rightarrow \mathrm{E}(2)$. The question is then, whether it would be natural or unnatural to unify all the interactions. A 'theory of everything' does possibly not exist, if the conjecture discussed here meets reality.

9 Conclusions

This article deals with the structural and dynamic similarities between natural systems, including non-living and living matter. Natural systems can be categorized into eight levels, according to their organizational complexity and evolutionary development. Ontological aspects of this level scheme were discussed. Building stones called 'units' and more complex structures called 'compounds' were defined on each level and filed in a kind of periodic table of natural systems. Compounds are able to adapt its structure to environmental impacts by reversible changes. The entirety of such states defines the 'state space' of the compound.

Two state spaces were defined at each level, a common space and an eigenspace. In the common space, only processes at a single organizational level occur, and the units, the building stones at this level, appear as stable, indivisible 'atoms'. In the eigenspace of compounds, processes at the next deeper level are present, where also the units act as composite systems. In general, compounds exist simultaneously in two state spaces: the common state and the eigenspace. This property of compounds is designated as spatial duality. Examples are given in the article for the spatial duality of compounds at six levels, the source domains of analogical reasoning. The conclusions concern the subatomic level, which is one of the target domains of the analogy.

Space time appears as the common space of subatomic particles such as leptons, hadrons, and photons. The eigenspace of these particles is missing, a result of analogical reasoning. This becomes obvious when properties such as the intrinsic spin or magnetic moment of point-like particles cannot be described within a space-time ontology[5]).

The definition of a basic space is proposed to fill this gap, that is, to represent the eigenspace of the subatomic particles. The basic space is located ‘below’ space-time according to the structural organization and chronologically ‘before’ space-time. The general consequences of this proposal are outlined in this article. A full discussion would need to develop a particle model with spatial duality, which is beyond the scope of this study (see [83] for the description of a corresponding model).

The proposed introduction of a basic space raises physical and philosophical questions regarding the nature of dark matter, dark energy, and the cosmic inflation. The role of gravity in the period of evolution before the emergence of space-time represents one of the most fundamental problems.

Whole-part relations were found at each level in two dimensions. In the vertical dimension, which is directed to the next higher level, compounds represent the whole and units represent the parts. The horizontal dimension is determined by the formation of a hierarchy of systems with an expansion in space-time and an ever-increasing number of compounds. These ‘complexes’ and higher aggregated systems represent the whole, and compounds represent the parts.

The method of analogic reasoning was formalized using quantors and logical operators known from the mathematical logic. A short form was demonstrated of deriving conclusions for relations at level L(1) using generalizations from the source levels L(2) to L(7).

10 Declarations

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Data availability statement: This manuscript has no associated data.

[5]) The mathematical representation of the spin in the Dirac theory and the Feynman diagrams used in calculations of QED (Quantum Electro-Dynamics) are successful mathematical theories, but they do not have an ontological explanation in space-time.

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