Classifying Phenomena Part 2: Types and Levels†

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Abstract : After making the case that phenomena can be the primary unit of classification (Part 1), some basic principles to group and sort phenomena are considered. Entities can be grouped together on the basis of both their similarity (morphology) and their common origin (phylogeny). The resulting groups will form the classical hierarchical chains of types and subtypes. At every hierarchical degree, phenomena can form ordered sets (arrays), where their sorting can reflect levels of increasing organization, corresponding to an evolutionary order of appearance (emergence). The theory of levels of reality has been investigated by many philosophers and applied to knowledge organization systems by various authors, which are briefly reviewed. At the broadest degree, it allows to identify some major strata of phenomena (forms, matter, life, minds, societies and culture) in turn divided into layers. A list of twenty-six layers is proposed to form the main classes of the Integrative Levels Classification system. A combination of morphology and phylogeny can determine whether a given phenomenon should be a type of an existing level, or a level on its own.

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† Michael Kleineberg has provided valuable suggestions on the formal properties of inclusion and on Hartmann terminology.

All true classification is genealogical—Darwin *On the origin of species by means of natural selection*

1.0 Introduction

This is the second in a series of papers devoted to the classification of phenomena. In the first part (Gnoli 2016), the dimensions of knowledge organization (KO) have been introduced, including reality in itself (α), phenomena (β), perspectives (γ), documents (δ), collections (ε), information needs (ζ) and people (η); it has been shown how a knowledge organization system (KOS) can give priority to one or another of these dimensions, perspective being the traditional choice for bibliographic classifications; and the alternative of phenomenon-based classification has been introduced as something worth to be developed and tested. Indeed, by privileging the perspective dimension, the disciplinary classifications that have been used in libraries and bibliographies impose some arbitrary grids to the organization and retrieval of the diversity of concepts discussed in documents: this is an unjustified assumption in ontological analysis in general, and also results in an obstacle to interdisciplinary research.

This second part will start examining the actual implementation of a phenomenon-based classification, by discussing on which bases phenomena can be grouped into classes, and how these can be arranged into ordered arrays and hierarchical chains of types. Like in the first part, examples of classes and their notation will be taken from the Integrative Levels Classification (ILC), the experimental developing scheme where the principles discussed in these papers are being implemented. However, the paper's focus is meant to be on general principles rather than on the details of this particular KOS.

We will show how two major structural principles by which phenomena can be classified are types and levels. In sections 2 to 4, types will be introduced in the context of the classical basic elements of classification, such as individuals, classes, arrays and their hierarchical organization. While these are necessary basic components of any good classification, a vast literature is available on them already; therefore, they will only be introduced briefly, in view of the more original discussion of the theory of levels and of its application to knowledge organization systems, which will be developed in sections 5 to 8. Despite these are acknowledged by a wide variety of authors in philosophy and in sciences, their formalization is still possible only in partial ways, as classification keeps being both a science and an art. Some aspects of the representation of types and levels, and of relations between them, will then be discussed in sections 9 and 10.

2.0 Individuals and classes

For any individual phenomenon, various relationships with other phenomena can be observed. The most basic relationship is identity $A \equiv A$: a phenomenon is identical with itself. This means that it keeps its identity in a certain range of space and time, and can be identified and named. For example, the animal living in the Oberhausen aquarium who made right "predictions" of match results in the 2010 football World Cup was an individual phenomenon called Paul.

Every individual has various characters, such as shape, parts, properties, behaviour, internal processes, position in an environment. Paul had a head, had eight tentacles, swam, moved towards team flags, etc.

By comparing individual phenomena, similarities of various kinds can be observed between some of them: $A \approx B$. This leads to identify more abstract groupings of phenomena, usually called "sets" in mathematics or "classes" in knowledge organization. The class of phenomena having a globose body with no external skeleton, a highly developed brain, two eyes with a crystalline lens, eight tentacles equipped with suckers, etc. can be called the class of octopodes. A class can be defined either extensionally, by listing all individual phenomena included: $Oct = \{\text{Paul}, ...\}$; or intensionally, by their defining characteristics: $Oct = \{x \mid \text{has globose body, has eight tentacles}, ...\}$.

An individual phenomenon is thus an instance of a class: $\text{Paul} \in Oct$ (in mathematical terms, it is a member of the set of octopodes); Paul is an instance of octopodes. Although similar in some shared characteristics, instances can all be different and unique. Not all octopodes are trained to select a national flag over another; octopodes also differ by size, age, accidental damages to one of their tentacles, etc. This makes it useful to coin proper names to designate some of them which are relevant to our discourse: a particular octopus is called Paul, a particular star is called the Sun, a particular city is called Lisbon.

Differences among individual phenomena tend to be more relevant in complex phenomena at higher levels of organization (see below), such as glaciers or octopodes or houses, while electrons or water molecules are harder to be distinguished from each other. When such individual differences become extremely relevant, the individual phenomenon may deserve to become a class on its own. This sometimes happens with newly-discovered animal specimens or language samples, that are provisionally assigned to an existing class, only to realize upon further analysis that they are a member of a different, previously unknown class. Although languages or animal species are usually considered to be classes, some authors have proposed to consider them as individuals, given their unique set of characters that have developed only once in evolutionary history (Ghiselin 1969 cited in Gagliasso 2001).

Sometimes, in a constructionist approach, the distinction between individuals and classes is considered to have an epistemological basis, as the former would be phenomena observed in the world while the latter would be constructed by classifiers. However, this distinction can hardly be an absolute one, as even the identification of an individual phenomenon is an implicit act of classification, as was observed in the preceding part (Gnoli 2016, section 3.0), and even the identification of a class is usually based on some prominent, actual characteristics. While everybody is allowed to build any classification based on idiosyncratic criteria, classifications shared and used by many people are mostly based on characteristics that have proved to be effective in explaining and generalizing a wide range of diversity. Mill (1872, cited in Hjørland 2013) called the latter "natural," as opposed to "technical or artificial." Clearly it is not always easy to tell what is natural and what is artificial, so that an actual KOS is a combination of both natural and artificial characteristics. Still, while some KOSs are intentionally artificial, the ontological approach to knowledge organization—that is, the approach focusing on the nature of the organized entities themselves (Gnoli 2011), already introduced in part 1—aims at making the natural component as prevailing as possible.

In the real world, different kinds of phenomena can be observed; for example, poems appear to belong to a realm substantially different from that of stones, or that of animals, as many properties and behaviours that can be observed in one of these cannot be observed in the others. Each of these realms behaves according to its own characteristic set of laws, which hold within it but not necessarily outside it. Animals undergo processes of reproduction, aging and death, while stones do not. Both animals and stones have a specific weight and are subjected to gravity, while poems do not. In ontological terms, different "categories" apply to different kinds of phenomena (Poli 2011). All this suggests that these different kinds should be represented in a classification as different classes.

3.0 Arrays of classes

A given number of classes can be arranged in a defined order, thus forming an array of classes (the term "array" is adopted after Ranganathan (1967, section CE)). In mathematical terms, a set of classes (or of individuals) arranged in a given order is called an ordered set, and is represented in parenthesess: (*a*, *b*, *c*, *d*...), as opposed to unordered sets which are represented in curly braces: {*c*, *b*, *d*, *a*, ...}. Every class will thus have a prescribed position as compared to another class: e.g., $a < c$, hence *a* has to be filed before *c* in any systematic display of classified items.

Identifying classes and listing them in a fixed order already is a basic form of classification. As mentioned in the first part of this study, this is one feature peculiar of classification as opposed to other KOS types: it produces a systematic arrangement of items that makes their browsing easier and provides an intellectual guide to their exploration. On the other hand, as the terms that represent classes depend on the particular language of the vocabulary, the alphabetical sorting of terms will not produce any systematic order (there is no special reason why octopodes should be listed close to oculists).

Classification schemes are then furnished with a notation system that assigns to each class a symbol, chosen in such a way that the numerical or alphabetical sorting of symbols will produce the desired systematic order.

4.0 Types

Between certain classes, inclusion relationships can also be identified, as classes are divided on the basis of their characteristics (Frické 2016). Octopodes are a subclass of cephalopods, a more general group of animals: $Oct \subset Cep$. A subclass is a concept belonging to a class but more specific than it, such that it can be said that elements of the subclass belong to the class, but not necessarily the opposite: while all octopodes are cephalopods, only some cephalopods are octopodes, e.g. squids are cephalopods but not octopodes.

By applying division into subclasses several times, a chain of classes can be generated (the term "chain" is adopted after Ranganathan, 1967, section CF). Octopodes are cephalopods, which are molluscs, which are animals: $Oct \subset Cep \subset Mol \subset Ani$. Inclusion as a relationship is irreflexive (octopodes are not a subclass of themselves, at least according to the mathematical definition of a "proper subset"), asymmetrical (as mentioned already, while all octopodes are cephalopods, not all cephalopods are octopodes) and transitive (as octopodes are cephalopods and cephalopods are molluscs, octopodes also are molluscs) (Stock and Stock 2013).

Each class in a chain can have sister classes, which are subclasses of the same class: both cephalopods and gastropods are subclasses of molluscs. Sister classes form an array that has to be arranged in a fixed order for the purposes of classification: gastropods can be listed before cephalopods (as gastropods are considered to be less "evolved," see below).

A system of arrays and their chains forms a classification tree, that is a connected graph with no cycles (Bollobás 1998). Hierarchical trees of inclusions form the most classical structure usually associated with the notion of classification, although the identification of classes and the order within arrays also are important components.

In the Western tradition, classification trees usually represent relationships between types and subtypes, although trees in the Chinese tradition would tend to pay a greater attention to part-whole relationships (Lee 2010). Sometimes this may become a matter of terms, as one could also take the population of all octopodes existing in the world as a "part" of the population of all cephalopods. In many KOSs both types and parts are represented as included classes or terms, e.g. many thesauri represent both types and parts by the "NT" (narrower term) relationship; however, in faceted classifications only types should be represented as subclasses, while parts should be represented as part facets, as it will be discussed in the next part of this study (Gnoli 2017).

To decide which classes should be included in one and the same class, technically one can consider any characteristic. We could, for example, group whales together with olive trees on the basis of their ability to provide us with oils; or whales together with elephants on the basis of their shared grey colour; or whales together with trouts on the basis of their general shape. But, as we are committed to an ontological approach (Part 1), we have to give priority to those characteristics which are ontologically the most meaningful, that is, which are relevant not only for immediate purposes, or at a shallow observation, but with reference to the nature of the phenomena to be classified.

Intuitively, one should thus group the most alike phenomena together, on the basis of their general similarity (morphology). However, as phenomena are often complex, it is not easy to decide which ones are the most similar. We can easily agree that whales go with other animals rather than plants, but, are they best grouped together with sharks or together with seals? We need some sound criteria by which the cumulative value of all similarities and differences can be assessed and can produce optimal groups. Numerical taxonomy offers statistical techniques for such purposes (Sokal and Sneath 1963), but still depends on the sets of characters chosen for the analysis. Further mathematical techniques that could help to develop a general formal theory of classification are explored by Parrochia and Neuville (2013).

One important principle to explain the diversity of phenomena is their origin (their phylogeny). Evolutionary origin (taking the word "evolutionary" in the broadest sense) can account for a large number of characteristics of a class of phenomena and allow to claim very general statements about them. Optimal classificatory trees should then group phenomena according to a twosome of macro-criteria, that is, both morphology and phylogeny. These correspond to the principles of, respectively, structure and origin, which are indeed the main bases, at various degrees, for most classifications. Clearly, relying on two different principles may also lead to conflicts between them: the interplay between morphology and phylogeny will be discussed in section 10.

5.0 Levels as a sorting principle

In an array, classes can be sorted by any arbitrary criterion. However, experience has shown that some criteria are especially useful. Ranganathan (1967, part F) lists eight "principles for helpful sequence," presenting them in a general order of priority: later-in-time, later-in-evolution, spatial contiguity (vertical, horizontal, circular, radial), quantitative measure (increasing, decreasing), increasing complexity, canonical sequence, literary warrant, alphabetical sequence.

The last three principles—canonical, literary and alphabetical—clearly are practical ones, so in developing an ontologically-oriented classification of phenomena they should be applied at a later stage (e.g. to specify the document dimension, δ) rather than as primary general criteria.

Two more principles, contiguity and measure, can be very useful to sort arrays of specific classes of phenomena, such as landforms or stars; but again, dividing all phenomena primarily into big and small, or according to their position in space, would seem unsatisfying (whales and trucks need not to be in the same main class; water on Earth and water on Mars should not be in different classes).

Especially relevant from a general point of view appear to be the principles "later-in-time," "later-in-evolution" and "increasing complexity," as they refer to more intrinsic characteristics of phenomena. Additionally, these three principles are often connected between them and to the phylogeny of entities; indeed, evolution happens in time, so that more evolved phenomena need to be also more recent; and complexity needs both evolution and time to develop, so that evolved, recent phenomena can also be complex (although not necessarily: bacteria still are numerically dominant over the more evolved forms of life; parasites are simple organisms often evolved from more complex ones). All this suggests that these three principles can be grouped and subsumed under some more general phylogenetic notion.

A relevant candidate to work as a very general sorting principle, which is connected to time, evolution, and complexity, is the notion of level of organization. It refers to the acknowledgment that classes of observed phenomena, such as animals, stones and poems, can be arranged in a series where the "higher" phenomena are derived from the "lower" ones in terms of historical origin—or, more generally, of logical priority, in the way one cannot conceive a hexagonal prism without the prior notions of solid, symmetry, and the number 6. Higher levels can thus be considered as being "logically deeper," in Charles Bennett's terms; indeed, before reaching them, a certain path must necessarily have been covered through a series of previous steps (Bennett 1988). One cannot obtain poems from stones without passing through the long evolutionary stages of cells, of animals made of cells, and of humans as creative animals able to conceive poems.

The higher/lower level metaphor evokes building, in the sense that in a construction the higher elements need to rest on the lower ones, in order to stay at their place without falling by gravity. Sometimes the same metaphor has been used to illustrate the conceptual structure of a book, by representing every chapter as a brick resting on some of the other chapters below it, or such conceptual models as the popular Semantic Web Layer Cake, where every technical component of the web lies on more basic ones. In this representation, even the whole world could be seen as a big building, growing upwards as new elements are progressively added on its existing floors. Animals are more complex than molecules, but could not exist without the prior existence of molecules. In the terms of Ranganathan's principles, they have appeared at a later time than molecules, are more evolved than them, and more complex than them. The same kind of relation can be observed between many different classes phenomena, so that it has been widely acknowledged as a general principle, as it will be seen in the next section.

We say that the class of the derived phenomena is a higher level, the existence of which presupposes that of lower-level classes, but at the same time adds something to them. Indeed, describing the new phenomenon only in terms of the previous ones would not be completely satisfying: such a reductionistic description would fail to account for the novel properties, like reproduction, aging and death in living organisms, which did not exist in their constituents alone. Although useful to understand the internal structure of a phenomenon, reductionistic descriptions are incomplete, until the additional properties of the higher level are acknowledged. Explaining that organisms are made of molecules is useful, but is not enough, as the definition of molecules does not include the notions of reproduction, aging and death.

6.0 Levels in philosophical sources

As the structure of any KOS has to be based on some theory (Gnoli 2016, 404), both types and levels should be referred to theoretical sources. There are many sources for the notion of types in the literature of logic, both philosophical and mathematical, that have been developed in detail since antiquity and the Middle Ages (Frické 2016).

On the other hand, sources on levels are probably less familiar to most readers, despite the fact that many authors in the history of knowledge have been aware of the existence of levels at least vaguely: so it may be useful to briefly review them here. Levels are often mentioned intuitively, without any specific analysis of their identity, nor any attempt at a complete list of them. Traces of this notion can be found already in Presocratic Greek philosophers (Mourelatos 1987). The naturalistic works of Aristotle then outline an ontology structured into different planes. Chinese philosopher Zhu Xi (also spelled Chu Hsi, 1130-1200) acknowledged that each category of things has its own special essence (*li*); some things do not have a mind, while others have, and yet others like brushes are not natural products; still all things, both natural and spiritual, including people, depend on the same ultimate reality (*taiji*).

During the Middle Ages, classes of phenomena were often represented as the steps of a ladder (*scala naturae*), ranging from the inanimate things on lower steps through animate things, up to humans and God; levels thus implied a gradient of nobility and value, hence material things were considered despicable; such libraries and museums as the one in Kremsmünster Abbey, Austria, even reflected this order in keeping their documents at lower or higher floors according to their subject.

Among modern philosophers, ideas of levels can be found variously in Pascal, Leibniz, Hegel, Mill, Comte, Spencer, Bergson, Whitehead, Teilhard de Chardin, Smuts, Jaspers, Peirce, Hartmann, Popper, Meehl, Bunge (Grolier 1971, 100-2; Juarrero and Rubino 2008). In modern and contemporary philosophy, the transition from lower- to higher-level phenomena is often called "emergence" (Lovejoy 1927; Meehl and Sellars 1956; O'Connor 1994; Bonabeau et al. 1995; Holland 1998; Goldstein 1999; Cunningham 2001; Morowitz 2002; Bunge 2003; Corning 2006; Davies and Clayton 2006). The term was first adopted in this sense, it seems, by English philosopher George Henry Lewes (1875). Its most spectacular and cited examples are the emergence of life on matter, and the emergence of minds on living organisms.

The idea of emergence can be interpreted either in a strong sense, as the appearance of something substantially new in the world, or in weaker senses, until reducing it to "supervenience" or to an epiphenomenon (a secondary effect) of a basically material substance, which is acknowledged priority in the physicalism of much contemporary analytical philosophy (Beckermann et al. 1992; Humphreys 1997; Wimsatt 1997; Rueger 2000; Campbell and Bickhard 2011).

Emergence has something mysterious, exactly in that the appearance of the new properties cannot be explained in terms of the pre-existing properties. Usually one limits herself to observe and describe the presence of the new phenomenon, before attempting any explanation for it. One feature common to many emergent phenomena is that they are originated from the interaction of elements of different kinds, which are involved in some "synergy" (Corning 2006); while adding oxygen to oxygen just produces more oxygen, combining oxygen with hydrogen can produce water. Lewes worded this by writing that, while the combination of similar elements gives a "resultant" quantity of the same thing, the combination of elements of different kinds can indeed produce new "emergent" things, which differ from their original constituents in quality, rather than just in quantity. Thus, higher levels are the result of particular rearrangements and organizations of several elements of lower levels. The relationship of a class of phenomena to such lower-level factors, e.g. of stone walls to rocks, can be worth recording for retrieval purposes (Gnoli 2013).

The idea that levels are "greater than the sum of their parts" has become popular among scientists, particularly in the context of biology. Indeed, the coexistence of different levels (genes, cells, tissues, organs, organisms, populations, species, ecosystems) in life forms is evident, as are their substantial differences from the lower material phenomena. Despite the reductionism widespread in physics, organic phenomena cannot be described by the laws of physics in satisfying ways; instead, they need different planes of explanation, requiring biology to be an autonomous science with equal status than physics (Jennings 1927; Woodger 1929; Redfield 1942; Novikoff 1945; Herrick 1949; Anderson 1972; Jacob 1974; Medawar 1974; Mayr 1982; Emmeche et al. 1997). Clearly, a similar argument can be applied to the differences between biology and psychology or between psychology and sociology.

As the perspective of biological evolution, introduced in the English culture of the nineteenth century by Darwin, Wallace, Huxley and Romanes, had become more widespread in philosophy of science, it could be combined with the observation of emergent phenomena. The evolution of organisms, from simple to increasingly complex and sophisticated forms, appears to be a sequence of emergent transitions (Smith and Szathmáry 1995), and many have thought that such notion can be extended beyond the organic realm, to the whole universe. This idea resulted at that time in such evolutionary philosophies as that of Herbert Spencer, although the principle was not always applied in a correct way, like in the sad case of so-called "social Darwinism," and it was common to read that some musical instruments (Sachs 1940) or dances or religions were supposedly more "evolved" than others. Today we speak about an "evolution" of the universe, from the Big Bang to increasingly more complex and extended objects, as well as of an evolution of such particular classes of phenomena as stars, soils, languages, or cultural artifacts (Gnoli 2006); but this in itself does not imply any judgement of value about the evolved phenomena. A more scientific approach to a general theory of evolution is being developing very recently (Tëmkin and Eldredge 2015; Gontier 2016).

Levels thus are not seen anymore as a static state of things, where one simply observes the contemporary coexistence of phenomena lying at a series of different planes; rather they are seen, at least generally, as derived ones from the others, in the same way as the tree of life forms originally conceived by Linné as a static system is now acknowledged to be an evolutionary tree. A movement of supporters of "emergent evolution" took form in the first decades of the twentieth century; its most known representatives are Samuel Alexander and Conwy Lloyd Morgan (Hobhouse 1901; Marvin 1912; Alexander 1920; Thompson 1925; Morgan 1923; Broad 1925; Wheeler 1928; Conger 1931; Sellars 1970). The origins and development of this movement are reconstructed in detail by Blitz (1992). Some of these authors put at the end of their list of levels a spiritual or supernatural level, usually impersonal, like in the case of Alexander's "deity."

Some years later, biochemist and science historian Joseph Needham spoke about "integrative levels," in the context of his materialist worldview in which the logical next step of progressive evolution would have been the fulfillment of social cooperation (Needham 1936; Pettersson 1996). Another materialist author, psychologist James K. Feibleman (1951; 1965), formalized the "theory of integrative levels" and the basic laws of relationships between levels; the notion was then applied in the behavioural sciences by Theodore C. Schneirla (Schneirla 1972; Greenberg and Tobach 1988). The word "integrative" refers to the fact that elements of a lower level, when combining, form not just an "aggregate" of lower-level stuff, but a new "integrate" with different properties and nature. While especially popular with reference to natural phenomena, this idea has also been extended to the social domain (persons, families, social groups, villages, states, international organizations) or to the elements of languages (phonemes, morphemes, words, phrases, sentences, texts) (Foskett 1963, 129-45).

Another suggestion that reality should be investigated at different levels is provided by quantum physics. Phenomena occurring at the subatomic level cannot be described in the usual deterministic terms of classical mechanics, but require probabilistic treatments. This would happen because they belong to a different kind of reality, that some authors even extend to include free will as a feature of the human mind (Heisenberg 1984; Nicolescu 2006).

In the tradition of German philosophy, a powerful theory of levels has been provided by Nicolai Hartmann (1940; 1952) as a major element of his renovated ontology, that is his theory of the structure of being. Unlike the British naturalistic tradition, Hartmann emphasized the separation between the four main levels of reality (the material, organic, mental, and spiritual ones) more than their continuity, although still claiming that each level bases its existence on the lower ones. Hartmann did not describe his strata in evolutionary terms, but these were easily interpreted in such perspective by Konrad Lorenz (1976), the author of basic research on animal behaviour and the general evolution of knowledge abilities; not liking the term "emergence," as its etimology can wrongly suggest something preexisting that now comes out, Lorenz preferred that of "fulguration."

Lorenz shared both the view of a levelled structure of reality and an evolutionary conception of epistemology with Karl Popper and Donald Campbell. Popper's levels are called "World 1," including matter and life, "World 2," the conscious mind, and "World 3," including such creations of the human intellect as art works, theories and (notably) documents, which corresponds to Hartmann's "objectivated spirit" (Popper and Eccles 1977). The acknowledgment of this cultural level and of its autonomy from human actions at the social level is an original contribution of these continental thinkers, while most English-speaking authors conclude their lists with the mental and social activities of humans. Campbell also contributed the notion of "downward causation," claiming that higher levels can have causal influences on lower ones, like when political decisions laying at the social level affect greenhouse gas concentration at the material one (Campbell 1990; Emmeche et al. 1997; Bedau 2002; Campbell and Bickhard 2011).

Ontological research with reference to levels has recently been resumed by Roberto Poli and others (Poli 2001; Baianu 2007; Mathews 2008). Of the four strata of Hartmann, Poli proposes to merge the first two (material and organic) and suggests that the other two (mental and social) should not be represented in a series but in parallel, as they reciprocally influence each other, thus producing a triangular model. Kleineberg (2016), also active as a KO author, abandons linearity completely in favour of parallel evolution, thus upsetting the very idea of levels.

These authors consider the word "ontology" in both its philosophical and its informational meanings, and believe that philosophical ontology, including the theory of levels, can indeed provide useful foundations for knowledge organization and management (contrasting or at least complementing epistemological, documental, cognitive and sociological approaches, which emphasize different dimensions of knowledge). The present study subscribes to such a view.

7.0 Levels applied to knowledge organization

As the pattern of levels can encompass all classes of phenomena, it offers a useful principle for the organization of knowledge into a general system. Indeed, several thinkers have received the idea as a valuable basis on which to build a classification of all the sciences. Among them are André-Marie Ampère (1775-1836), Auguste Comte (1798-1857), Isidore Geoffroy Saint-Hilaire (1806-1861), Patrick Edward Dove (1815-1873), Friedrich Engels (1820-1895), Ernest Cushing Richardson (1860-1939), James Duff Brown (1862-1914), Henry Evelyn Bliss (1870-1955), Bonifati Mihailovic Kedrov (1903-1985), Louis Glangeaud (1903-1986). Recently it was suggested that "levels ... offer the possibility of a new taxonomy" (Nicolescu 2006, 6).

Application of genetic evolutionary principles to the classification of e.g., soils, climates, organisms, languages, musical instruments or religions, as well as to general classifications, have been discussed and reviewed already (Gnoli 2006; Tëmkin and Eldredge 2015); here we will limit our discussion to some traditions that are especially relevant for the phenomenon-based approach in the field of knowledge organization.

Peter Mark Roget's *Thesaurus*, the early terminological system presenting English words in alphabetical order, also had a systematic presentation which followed a sequence similar to that of levels: abstract relations, space, matter (general, inorganic, organic), intellectual faculties, voluntary powers, sentient and moral powers (Roget 1911). This was adopted recently as one system for browsing entries in the *Wikipedia*.

J.D. Brown's *Subject Classification*, already mentioned in Part 1, was based on a sequence of "matter, life, mind, and record," closely matching the major levels outlined above (Brown 1906, 12):

> Matter, force, motion and their applications are assumed to precede life and mind, and for that reason the material side of science, with its applications, has been selected as a foundation main class on which to construct the system. Life and its forms, arising out of matters, occupy the second place among the main classes .... Human life, its varieties, physical history, disorders and recreations, follows naturally as a higher development.

Classificationist Richardson also claimed that "the order of the sciences is the order of things," and "the order of things is lifeless, living, human, superhuman" (Richardson 1930; Dousa 2009). This kind of ontological sequence is described as "serial classification" by Bhattacharyya and Ranganathan (1974, 125); they observe that it is based on "Comte's claim that each subject is virtually an application of the preceding one," and mention Ampère and Spencer as its followers. Ampère's sequence differs from the others in that he places the applied disciplines just after the corresponding pure ones: physics, engineering; geology, mining; botany, agriculture; zoology, animal husbandry, medicine. Ranganathan follows this order in listing the main classes of his Colon Classification, although these also obey an original bell-like pattern of increasing "concreteness and integralness" with a peak in spiritual experience, followed by a progressive decrease in "naturalness" (Bianchini, Giusti and Gnoli 2017).

Bliss found that the disciplines of knowledge could be arranged according to "the order of nature," which is dynamic and developmental: "this development has evidently arisen from the inorganic and has extended upward thru the biologic into the mental and the social" (Bliss 1929, 179). Disciplines in his Bibliographic Classification are listed in an order of "gradation by speciality": first those dealing with all phenomena, that is philosophy, mathematics, and physics, then those dealing with increasingly special phenomena, that is biology, psychology, sociology, etc. This order was kept in the second, faceted edition of the Bliss Bibliographic Classification (BC2), edited by Jack Mills and other members of the Classification Research Group (CRG) since the 1970s. In the same period, Eric Coates and other CRG members adopted a similar order for their Broad System of Ordering (BSO).

Similar, though maybe less sophisticated, attempts at a classification based on an evolutionary arrangement of knowledge objects were also performed by Ejnar Wåhlin (1963), Martin Scheele (1977) and Alexander Shpackov (1992). Ingetraut Dahlberg's Information Coding Classification also has 10 main classes of knowledge objects inspired by Hartmann's ontology: form and structure, energy and matter, cosmos and Earth, bio, human, socio, economy and technology, science and information, culture (cf., Dahlberg 1978, 28-31). It is interesting to notice that this list extends beyond the naturalistic domains to also include technological and intellectual products (Hartmann's spiritual stratum), which seems necessary if the theory of levels has to be applied consistently throughout a general scheme. Hartmann and Poli also are important references in the application of levels theory to the General Formal Ontology developed by Heinrich Herre's research group at the University of Leipzig (Herre 2013), a good exception to the general negligence of levels in most digital ontologies.

The CRG explicitly considered integrative levels, as presented by Needham and Feibleman, as the basis of a general classification scheme (Spiteri 1995; Justice 2004; Gnoli and Poli 2004). Ideas in this direction were adumbrated already by CRG members Brian Vickery (1957; 1975, Appendix A), Barbara Kyle (1958) and Leo Jolley (1968). But it was especially Douglas Foskett who proposed to take Feibleman's theory as the basic structuring principle by which phenomena could be ordered, so to produce a list of phenomena instead of disciplines (Foskett 1961; 1963; 1970a; 1970-b; 1978). His model was in good agreement with Jason Farradane's principle of unique definition (Farradane 1950); indeed, levels provide a specific place for the definition of each phenomenon, that can be expressed in a notational symbol, which will not change when its relationships with phenomena of different levels are discussed in documents (CRG 1961, 163):

> The question of grouping entities within the main category [of Things] was discussed, and Mr Foskett suggested that the use of a concept such as "levels of integration" might be helpful. No other similar proposals were advanced, and it was thought that the application of this concept might be worth considering. Members of the Group agreed to re-read the statement by Joseph Needham (which is given in his book *Time the refreshing river*) and to try applying the concept to entities in fields in which they were familiar. Note: Mr Vickery also deals with the exponents of the theory in Appendix A of his book (Vickery 1975).

The CRG worked for several years to explore the possible structure of a new general classification scheme, using a grant by NATO (CRG 1969). Many features and problems of it were considered in the group meetings. Discussions were filled with original and interesting ideas, but members had different opinions about them, and could not reach a common conclusion on the final structure of the scheme. However, Derek Austin (1969a; 1969b; 1972; 1976) produced concrete drafts of its schedules and of how it could work by his principles of freely faceted classification.

Then the grant was not renewed, and Austin became busy with another big project concerning verbal subject indexing at the British National Bibliography, which took the form of PRECIS, the Preserved Context Indexing System. In the meantime, Mills, Coates, Foskett and others began to focus on the new edition of the Bliss Classification. Although not being a classification, PRECIS inherited many features of Austin's previous work, especially for what concerned the free combination of concepts by role/facet operators. In turn, this influenced the formulation of similar principles by the Italian Research Group on Subject Indexing (GRIS), which are now partially introduced in the Nuovo Soggettario, the general thesaurus developed at the Central National Library of Florence; application of the theory of levels to Nuovo Soggettario, which would be consistent with this tradition, was indeed considered by editors Alberto Cheti and Anna Lucarelli under stimulation by the present author, but have not been implemented yet.

In this spirit, the Integrative Levels Classification project has started to resume experimentation with a classification of phenomena arranged by levels and combinable as free facets (Gnoli et al. 2011). Levels theory appears in the very name of ILC, as early project member Lorena Zuccolo found that this name was less ambiguous than the previous draft name "Naturalistic Classification." The list of ILC classes is partially different from those produced by the CRG, and the subsequent development is independent from them, still the works by Foskett and Austin must be seen as its main references.

The main idea in this approach is that, while chains of classes and their subclasses continue to represent inclusion relationships between types (Section 4), as it happens in the hierarchical trees of all classical systems (e.g. organisms, including animals, including molluscs, including cephalopods, etc.), arrays of classes represent series of levels (e.g. populations, depending on organisms, depending on cells, depending on genes, etc.):

– types form chains connected by inclusion; and,
– levels form arrays connected by dependence (emergence).

Indeed, the emergence relationship between levels is one of existential dependence (Lowe 2005), meaning that the existence of the higher level depends on the existence of the lower one. Therefore, this kind of classification introduces another kind of relationship between classes, besides inclusion: that is, the dependence relationship (Gnoli et al. 2007; Gnoli et al. 2015; De Santis and Gnoli 2016). This relationship is potentially useful also for other KOS types, such as thesauri (as in Roget's *Thesaurus* and *Nuovo Soggettario* discussed above) or ontologies (De Santis and Gnoli 2015).

In other systems, the sequence of classes in arrays is often established in arbitrary ways or according to a variety of intuitive principles, summarized by Ranganathan's eight principles for helpful sequence. In a system based on the theory of levels, on the other hand, arrays should reproduce wherever possible a sequence of consecutive levels. This means that if a class of phenomena *n* depends on another class *h*, then *n* has to follow *h* in the relevant array of classes:

$h < n$

Notice that this does not necessarily imply that every class depends on the previous adjacent one in the same array. Indeed, the network of dependence relationships is more complex than a single sequence. A given class of phenomena often depends on several classes at lower levels, having emerged out of a synergy of them: motor vehicles depend on chemical substances and reactions as for their fuels, but also on the flat shape of land as for their wheels mechanics, on the anatomy of the human body as for the ergonomy of their seats and instrument panel, and on the state of technological knowledge as for their overall design. As one purpose of classifications is to enable browsing by presenting classes in a linear sequence, the complexity of such network of dependences need to be reduced to an ordered set (Section 3). What is relevant here, however, is that phenomena at higher levels should not be listed before phenomena at lower levels on which they depend.

8.0 Identifying the major levels

Hartmann introduced in the theory of levels a strong distinction between major "strata," or planes, of reality (the material, the organic, the mental, and the spiritual) and minor "layers" existing within them, of which the typical example are those within the material stratum (atoms, molecules, bodies, etc.) and within the organic stratum (cells, organisms, populations, etc.). While layers are in a relation of "superformation" (*Überformung*) between them, meaning that each of them is made with elements of the lower one, strata are in a relation of "superposition" (*Überbauung*), meaning that lower strata are a previous condition for the existence of higher ones, but not as their material constituents. Organisms are required for minds to exist, yet minds are not made of organisms (Hartmann 1940; Poli 2001).

Which is, then, the nature of the superposition relationship? This is maybe the most difficult aspect of emergence. The body-mind relationship, perhaps the main single problem in the whole history of philosophy, corresponds to the boundary between the organic stratum and the mental stratum, and is often cited as a case of strong emergence; as mentioned, Nicolescu (2006) looks for a solution by postulating a quantistic stratum, shared by both subatomic particles and minds, although this seems to make things even more complicate (Poli 2009).

A promising clue is offered by the observation that all major transitions in evolution correspond to the establishment of some mechanism of memory (Jacob 1974). Indeed, the cultural stratum emerges where humans share the memory of their knowledge through cultural transmission; the mental stratum emerges where the external situation is recorded in the memory of an individual as percepts and concepts; and even in the organic stratum, the anatomy, physiology, and behaviour of organisms can be seen as a form of knowledge about the environment to which they are adapted, recorded in their genome. Lorenz (1976) illustrates this with the examples of the hydrodynamic shape of fishes, viewed as knowledge about the mechanic properties of water in which they have to live; and of the structure of horse hooves, viewed as reflecting the shape of the steppe in which they have to live. Thus, superposition can be seen as a representation of patterns of a lower stratum into a new kind of medium: a case of formal dependence, as opposed to the material dependence between layers.

In a phylogenetic view, each stratum undergoes a different kind of evolution producing its own diverse forms: material, living, conscious, social, cultural. "Organization" at a new stratum takes place when forms ("phenotype") are produced indirectly by some separate replicators ("genotype") where information about the environment can be stored and accumulated (Boulding 1977). Replicators can occur in different varieties, which are selected by the pressure of external factors, so that in time they develop patterns that model the external environment more accurately.

Genes, brains, socially shared ideas (sometimes called "memes" or "inscriptions") and recorded documents all are well-known memory devices. Ideas can also be shared in some animal societies, like the ability to wash sweet potatoes having spread in a community of Japanese macaques; however, their transmission in human societies is much more efficient thanks to the appearance of language, that acts as another major replicator of patterns; similarly, the invention of writing systems and other technologies opens the road for the further stratum of artifacts and "mentefacts" (Kyle 1958) transcending the actual presence of people who had generated them. It is less clear what replicators can exactly be in the material stratum, where replication often takes the aspect of some mould reproducing a shape, like in enzymes or minerals.

Memories at different levels allow systems for performing different processes. Material systems react to external perturbations in a mechanical way, by simply changing their own structure. Organic systems, thanks to their genetic memory, are able to react in more sophisticated ways, thus tending to keep their internal state unaltered (homeostasis).

Social systems, thanks to their linguistic memory, are even able to change their external environment according to their own purposes (Hofkirchner 2012). A further kind of memory could be identified as that stored by humans into external artifacts, like machines, robots, books, or the semantic web, which are able to promote changes in the environment in absence of their original creators. A framework of the evolution of different forms of organization can thus be envisaged (Gnoli and Ridi 2014).

These observations support a view of reality as structured into at least six major levels, each one representing patterns of the previous one in networks of a novel nature:

– forms
– matter
– life
– mind
– society
– culture

These major levels more or less correspond to the four strata of Hartmann, with the further division of his spiritual stratum into a social level (Hartmann's "objective spirit") and a cultural level (his "objectivated spirit"). We have also added an initial level of forms, consisting of abstract logical and mathematical structures; these are described by Hartmann, following a philosophical tradition, as falling in a realm of "ideal being" separated from that of "real being," which includes all the other strata.

The location of logical and mathematical structures is indeed a critical question in any model of the world: many see them only as constructions of the human spirit, hence lying in the mental stratum (like in Kant) or even in the cultural stratum. A naturalistic approach can instead suppose a prior existence of forms independent from the human notion of them: this model was adopted among others by Walter Marvin (1912), who listed the logical-mathematical, physical, biological, mental, human and social levels. Feibleman (1951, 332-56) also listed three "theoretical" levels, ontological, logical, and mathematical, preceding the "empirical" levels. The reappearance of forms in the higher strata of mind and culture could be explained in terms of evolutionary epistemology: indeed, the notions of number, logical operations, etc. may have evolved in human minds as careful representations of the structure of reality, which makes them working well in everyday interactions with the environment, hence useful for the organism fitness. All "real" strata from matter onwards could then be viewed as representations of the basic "ideal" level of abstract forms, in the sense that they make them actual in concrete objects and processes. This is intuitively acknowledged in many KOSs, including Roget's *Thesaurus* and Dahlberg's Information Coding Classification, by placing the concepts of logic and mathematics at the beginning of the schedules; ILC will do the same with main class *a* "forms."

Other debated issues concern the status of the organic stratum, as authors like Popper and Poli see it as just a part of the material one; and the identity of the highest strata, often described as "social" rather than "spiritual" since Roy Sellars, and seen by Poli as tangled with the mental rather than lying above it. As mentioned above, Alexander even claimed that the highest level is that of an impersonal "deity."

Our list of the major levels can thus be compared with the terminology of some philosophers dealing with levels (Figure 1).

Some strata can be decomposed quite easily into their layers: e.g. for Morgan matter can be either physical or

<table>
<tr><th></th><th>Lloyd Morgan</th><th>RW Sellars</th><th>Hartmann</th><th>Poli</th><th>Popper</th></tr>
<tr><td>form</td><td colspan="2"></td><td>ideal being</td><td colspan="2"></td></tr>
<tr><td>matter</td><td>matter</td><td>inanimate</td><td>material</td><td rowspan="2">material</td><td rowspan="2">world 1</td></tr>
<tr><td>life</td><td>life</td><td>animate</td><td>organic</td></tr>
<tr><td>mind</td><td rowspan="2">mind</td><td>mind</td><td>psychic</td><td>psychological</td><td>world 2</td></tr>
<tr><td>society
heritage</td><td>society</td><td>personal spirit
objective spirit
objectivated spirit</td><td>social</td><td>world 3</td></tr>
</table>

Figure 1: Proposed major levels as compared with those of some philosophers.

chemical, while mind can be conscious or reflective; for Hartmann, the spiritual stratum includes personal, objective (social), and objectivated (cultural) spirit. Modern science acknowledges matter as including "branes," subatomic particles and waves, atoms, molecules, celestial objects; and life as including cells, organisms, and biological populations. Other layers are identified less immediately, but levelled structures are often cited, e.g., minds can include a series of increasingly conscious states, while families, clans, cities, nations, and the global community can be listed in the social stratum.

These subdivisions of the major levels can obviously be represented as the main classes of a system, which in turn can be subdivided into further types (atoms into the known chemical elements, organisms into algae, fungi, plants, animals, etc.). Although such more detailed types are rarely called "levels," they also are the product of some evolution so they can be internally sorted into arrays, at least in principle, according to their order of appearance.

9.0 Representing levels in arrays

The sequence of classes within an array is represented in ILC by a sequence of lower-case letters between *a* and *z*. Such sequence reflects an order of appearance, usually also corresponding to increasing organization and sophistication. This is the sequence of the most general levels of phenomena: forms, matter, life, mind, society and culture, each with its own layers:

* anything

a forms

matter
- *b* spacetime
- *c* branes
- *d* energy
- *e* atoms
- *f* molecules
- *g* continuum bodies
- *h* celestial objects
- *I* weather
- *j* land

life
- *k* genes
- *l* bacteria
- *m* organisms (eukaryote)
- *n* populations

minds
- *o* instincts
- *p* consciousness
- *q* signs

societies
- *r* languages
- *s* civil society
- *t* governments
- *u* economies
- *v* technologies

culture
- *w* artifacts
- *x* art works
- *y* knowledge
- *z* religion

~ everything

While we have the identified six major levels, the Roman alphabet offers symbols for twenty-six main classes. Probably the latter figure is not just a chance, but an effect of the natural "futility point," that is, the number of objects (including written letters) that humans find comfortable to browse without need for grouping them into greater units, which is known to equal some tens (Blair 1990). A list of one hundred main classes would be unpractical, and a list of four main classes would be too simple. A notational system using the twenty-six letters from *a* to *z* then looks quite suitable to express an appropriate number of integrative levels. For this reason, the ILC system adopts for the six major levels what Ranganathan calls a telescopic notation, and directly begins by representing their layers by single letters. These are still listed in the order of the stratum to which they belong.

Of course, these are the levels that can presently be identified by human knowledge abilities. More levels could be identified later, especially towards the beginning of the series (as in the case of "branes" hypothesized by contemporary fundamental physics), and others aspects of reality could even rest unknown forever.

The series of main classes is preceded by symbol * standing for the original, undifferentiated reality yet to be divided into classes (the absolute, apeiron, Tao etc.: see part 1), and followed by the symbol ~ standing for the system of the whole world in all its articulations and complexity.

Every main class can be divided into types by further lowercase letters:

m organisms
...
mf fungi

mp plants
mq animals

Here the sequence *f*, *p*, *q* carries at one time the morphological information that fungi, plants, and animals are three different varieties of a same phenomenon (*m* organisms); and the phylogenetical information that they have presumably appeared in this order and are increasingly organized (indeed, animals are on average more complex and autonomous than fungi and plants).

As noticed above, this does not imply that a class is derived from the adjacent previous one, that is, that animals have emerged from plants. Plants and animals can be two independent branches in the evolution of organisms, with animals appeared later than plants.

However, the reverse implication holds: if a class emerges from another one, it must be expressed by a higher letter than it (either the next one or any subsequent one). Mammals emerged from *mqvl* "reptiles," thus they are represented by *mqvt* which is greater than *mqvl*, although another level *mqvo* ("birds") is interposed between them (which, again, does not mean that mammals have emerged from birds).

10.0 Representing morphology and phylogeny

Like in all decimal classifications with an expressive notation, each further letter in the symbol of a class expresses a further degree of specificity: *mqvo* "birds" is a more specific concept than *mqv* "chordates." Chains of types are thus another component in a classification, orthogonal to arrays of levels. While an array expresses an evolutionary sequence of increasing derivatedness, a chain expresses a typological sequence of increasing specificity (Gnoli 2010).

These orthogonal components together represent what can be imagined like a big tree of all phenomena, and the relationships between them in terms of both the principle of origin (phylogeny) and that of similarity (morphology). In some cases, however, the two principles conflict. Whales, sharks, and ichthyosaurs all have a similar shape, but this does not depend on their origin. Rather than being a sign of historical relatedness, hydrodynamic shape has evolved in animals three times independently, due to similar environmental conditions (and later it has evolved again in submarines). Such kind of similarity is called "analogy." On the other hand, fish fins, bird wings, and human arms all have a common evolutionary origin, despite their different shapes and functions: this is then a case of "homology" (Minelli and Fusco 2013).

The ontological approach suggests that we keep homology in not lesser greater consideration than analogy, as common origin often has a bigger explanatory power of the nature of phenomena than has shape similarity alone. Once we know that two objects are historically related, we understand their structure in deeper ways, and on this basis we can also predict further characters not manifest at initial inspection: knowing that whales are mammals allows us to predict that they breathe by lungs and suckle their offspring, without need of checking this directly for every new whale individual that is discovered.

All this suggests some general guidelines on where a given phenomenon should be placed in the classification schedules and how should it be represented in notation. That is, it should be listed near the most similar phenomena among those having a common origin with it, and not before the phenomena from which it presumably originated. More in detail, the question is to establish the appropriate degree of specificity (i.e. of notation length) for the new phenomenon.

Let us consider the phenomenon of birds. Although aircrafts fly just as birds, birds clearly are a kind of organisms, so have to be filed somewhere under *m* (unlike aircrafts). Also, research in biological evolution found that birds originated from some ancient type of reptiles. Hence they cannot be listed before *mqvl*.

A purely phylogenetic approach (called in biology a cladistic approach, see Kitching et al. 1998) would suggest that birds can then be considered as a type of reptiles: *mqvlX*, where *X* stands for any further lowercase letter. However, classificationists paying more also attention to morphology will observe that birds have evolved into forms very different from those of their reptile ancestors, suggesting that they deserve a separate class rather than just a subclass. Establishing of the specificity of this class depends on how much different are birds from other organisms. This was already acknowledged by Darwin (1859, ch. 3, emphasis original):

> I believe that the *arrangement* of the groups within each class, in due subordination and relation to the other groups, must be strictly genealogical in order to be natural; but that the *amount* of difference in the several branches or groups, though allied in the same degree in blood to their common progenitor, may differ greatly, being due to the different degrees of modification which they have undergone; and this is expressed by the forms being ranked under different genera, families, sections, or orders.

The possibilities are:

mqvlX	birds are nothing but a kind of reptiles
mqvX	birds are chordates different from reptiles
mqX	birds are also different from chordates
mX	birds are even different from animals
X	birds are a level autonomous from organisms

A formal principle to determine the appropriate degree of difference would require a precise measurement of morphological difference, a parameter for which no absolute measure is available. Therefore, classification usually proceeds in a more intuitive way. Zoological knowledge suggests that birds are different from reptiles, but still share most characters with the other chordata, so that their best placement is *mqvX*. As they originated from reptiles, *X* must be greater than *l*. The letter *o* can be chosen as it remembers of the word *ornithology* (*b* from *birds* is not suitable as it would precede *l*):

mqv chordata
...
mqvl reptiles
mqvo birds
mqvt mammals

While we keep developing classifications applying general principles in such intuitive ways, we may look for more formal and objective parameters to establish the degree of similarity between phenomena. An important aspect of such research is the measurement of grades of organization that should indicate the appropriate types and levels to which phenomena are to be assigned.

The notion of grade has been proposed by biologist Julian Huxley (1958), to account for related groups of organisms that have evolved structures of different complexity. A classical case is indeed that of birds, which according to strict cladistic criteria should be listed as a type of reptiles because they have evolved from certain reptiles only after some other reptile groups; on the other hand, birds have differentiated very much from all other reptiles in developing feathers and other characters, which persuades many taxonomists to list them as a separate class anyway. Huxley noticed that humans are another such case as, despite having evolved as just a branching of apes, they have developed exceptionally different characters such as language, technology and spirituality, that have a profound impact on the natural world; this could justify even to list them as a new phylum, that of "psychozoa." While biological taxonomy does not acknowledge such a proposal, this is implemented in practice in the more general classifications, which after biology have classes for these exceptional characters of humans, that is the whole of psychology, sociology and the humanities.

In recent decades, complexity theory has developed a similar search for an absolute measure of complexity. A promising notion in our perspective is that of logical depth (section 5), someway expressing the derivatedness of a phenomenon: logically deep phenomena are derived from an evolution of shallower ones, with the accumulation of new properties in the process.

To draft at least a simple model, a suitable case is provided by chemical elements. Indeed, each element differs basically for its atoms having one proton and one electron more from the previous elements: the addition of them (together with some neutrons) is enough to determine most properties of the new element (as my high school teacher Clementina Morales once said: "aren't you shocked that, just by adding one electron, an atom becomes another one?!"). In Foskett's words (1961, 141): "The periodic table of the elements illustrates very well one of the "laws" of the integrative levels, in that small changes in atomic structure are enough to make a clear difference between two neighbouring elements.

As elements are level *e* in the ILC schedule, let us represent by *eb* the most simple elements, having only one energy level, and by *ebb* the most simple among them, hydrogen (H), having one electron in its only energy level. Therefore we can say its notation N to be an ordered set of symbols:

$$N(\mathrm{H}) = (e, b, b)$$

More in general, the notation N of any phenomenon p will be an ordered set

$$N(p) = (N_1, N_2, N_3, \ldots, N_n)$$

Now let us consider the next element, helium (He): it has two protons and two electrons, still in one only energy level. Comparing it with hydrogen, it has one additional character (having a second proton-electron pair). Hence we can suppose that logical depth has increased by one order of magnitude. To represent this, we can change the last symbol N_n in our ordered sequence from *b* to *c*:

$$N(\mathrm{He}) = (N_1, N_2, N_3) = (e, b, c)$$

More in general, in notation

$$N(p) = (N_1, N_2, \ldots, N_i, \ldots, N_n)$$

we will change the symbol N_i where i reflects the amount of change in logical depth.

Moving to the next chemical element, lythium (Li), we find not only one more proton-electron pair, but also a new energy level: indeed, the new electron is not at the same level as the previous two, but at a more external and energetic level. Therefore, logical depth has increased by an additional order of magnitude, so that this time we have to change symbol N_2:

$$x(\mathrm{Li}) = (N_1, N_2, N_3) = (e, c, b)$$

In this way, we obtain a schedule of chemical elements whose notation expresses their progressive increase in organization:

eb atoms with one energy level
ebb hydrogen
ebc helium
ec atoms with two energy levels
ecb lythium
ecc berillium
ecd boron
ece carbon
ecf nitrogen
ecg oxygen
ece fluorine
ece neon
ed atoms with three energy levels
edb sodium
edc magnesium
[etc.]

Using Roman letters to represent types allow to have until twenty-six sister classes in an array. In most cases this is enough, and where a class has less than twenty-six types some letters will not be used. Indeed, notation should reflect the tree of concepts it represents, rather than acting as a Procrustean bed by imposing its own structure to them.

However, some phenomena are clearly divided into more than twenty-six types which have the same importance. For example, period 6 elements, eg., include fourteen lanthanides, which together with the eighteen regular elements amount to thirty-two types. Such cases can be managed by what Ranganathan, who introduced them, calls "empty digits," that is symbols that are not used to represent a subclass, but only to introduce a further set of interpolated subclasses. As it is convenient that empty digits be the last symbol in a notational zone, ILC adopts *z* for this purpose. This means that *z* is never used to represent a subclass (only *a* to *y* are used to this purpose), but only to introduce further subclasses of the same array. These can be interpolated wherever necessary, thus making *z* also suitable to update a classification when new phenomena are discovered, without forcing their position according to the limitations of available notation. Therefore, period 6 elements can be represented as follows:

eg period 6 elements
egb caesium
egc barium
egcz lanthanides
egczb lanthanum
egczc cerium
...
egczo ytterbium
egd lutetium
...
egs radon

We have used examples from the classification of atoms and of organisms, as they are classical and easy to understand. However, the same dialectic between morphological and genetical principles can be found in the classification of other phenomena, like climates, languages, or religions. Musical instruments have often been classified by morphological principles, still their history often provides significant contributions to their systematics. Zithers include board zithers, where strings are attached directly to a soundboard like in the harpsicord, and frame zithers, where strings are attached on a frame. Pianos are usually classified with board zithers as their strings were originally attached to the soundboard; however, modern pianos have a cast iron frame (plate), which strictly speaking would make them frame zithers. Similar cases concern the crowth (lyre or not?), and some musical bows (simple or compound chordophone?). We contend that phylogeny should always be taken into account (together with morphology) when deciding the location of a class.

11.0 Conclusion

This paper has continued the discussion of basic principles for the classification of phenomena, that had started by the identification of dimensions in knowledge organization. It has addressed the core questions of how phenomena should be grouped into classes, based on both their similarity (morphology) and their common origin (phylogeny).

Although no absolute quantitative methods are available yet to measure the similarity between phenomena, or their absolute complexity, some general principles have been identified that should be followed in the development of such a classification. At the broadest degree, the theory appearing to be the most useful to this purpose is that of levels of reality. Indeed, this theory has been applied to a variety of existing KOSs in more or less explicit ways.

Levels can be easily represented as arrays of classes, the order of which should follow their evolutionary order of appearance. Every level can be divided orthogonally into types, which in turn should be listed in their order of appearance, and so on.

Of course, this general structure cannot be perfect since the beginning, but its details have to be developed and tuned according to the most recent developments of knowledge as well as to experience with the new system.

The combination of levels and types can provide the basic framework for a classification of phenomena. To model the relationships between phenomena with greater accuracy, such a classification can also take advantage of further structures identified by classification theory, such as facets of a class (Gnoli 2017) and themes co-occurring in the same document. These will be the subject of further papers.

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