Levels of Reality and Levels of Representation

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ABSTRACT: Ontology, in its philosophical meaning, is the discipline investigating the structure of reality. Its findings can be relevant to knowledge organization, and models of knowledge can, in turn, offer relevant ontological suggestions. Several philosophers in time have pointed out that reality is structured into a series of integrative levels, like the physical, the biological, the mental, and the cultural, and that each level plays as a base for the emergence of more complex levels. More detailed theories of levels have been developed by Nicolai Hartmann and James K. Feibleman, and these have been considered as a source for structuring principles in bibliographic classification by both the Classification Research Group (CRG) and Ingetraut Dahlberg. CRG's analysis of levels and of their possible application to a new general classification scheme based on phenomena instead of disciplines, as it was formulated by Derek Austin in 1969, is examined in detail. Both benefits and open problems in applying integrative levels to bibliographic classification are pointed out.

1: Introduction

The events and objects of our experience are classified in many different ways: some forms of classification depend on the way in which events and objects are described, according to either our perceptions or our conceptualizations (e.g., in terms of salient features); while other classifications depend on general patterns, or "universals", wholly intrinsic to the events and objects of the world. We may call these two opposite forms of classification *epistemological* and *ontological*. The purpose of this paper is to show that both ontological and epistemological analyses unfold in degrees or levels, and to explore relations between such levels and their possible representation in classification. As a traditional tool to organize knowledge, bibliographic classifications are especially considered, and their relation with the theory of levels is examined.

The ontological approach is perhaps the most distant from the contemporary scientific perspective. For this reason, some brief words of clarification are advisable. It should first be noted that for some time the term and idea of "ontology" have begun to enjoy currency in various sectors of artificial intelligence, and particularly in (1) representation of knowledge; (2) theory of databases; (3) natural language processing; and (4) automatic translation. In short, those who most frequently talk about ontology are researchers in the acquisition, integration, sharing and re-utilization of knowledge. Ontology comes into play as a viable strategy with which, for example, to construct robust domain models. An ontologically grounded knowledge of the objects of the domain should make their codification simpler, more transparent and more natural. Indeed, ontology can give greater robustness to models by furnishing criteria and categories by which to organize and construct them; it is also able to provide contexts in which different models can be embedded and recategorized to acquire greater reciprocal transparency (Poli, 1996; Poli & Mazzola, 2000; Poli, 2001*a*; Poli, 2002). Furthermore, it may be proved that ontological analyses ground epistemological analyses (Poli, 2001*c*).

2: How much information is there?

Let's consider the pen in front of me on my desk. What type of object is this pen? How should I model it? First of all, I may say that the pen is an object made in a certain way, with its own shape, colour and material. In saying this, I am using concepts that describe the physical world of things. The pen must also perform functions: it has been designed to write. This reference to function introduces a different dimension into the analysis: writing, in fact, is not something that I can model using only concepts describing the physical world. Writing is an activity typically performed by humans. By virtue of being constructed to fulfil the function of writing, the pen is in some way connected with this aspect of the world. But when I observe the pen, it tells me many other things. For example, that it has been constructed by somebody, and that this somebody is my contemporary: this pen is not an object from the Roman age or from ancient China. The material from which it is made, its manufacture, the way it works tell me that there must be somewhere an organization producing things like pens. If we now shift our focus to this organization, the pen must be an object designed, manufactured and distributed so that it can be sold and end up on someone's desk. In their turn, the points of view of the designer, of the production department and of the distribution department are different, and they describe my pen using different concepts. For the designer the pen is essentially an aesthetic and functional object; for the production department it is the outcome of materials processed in a certain way, etc. For the company producing the pen it is all these things together. For the shopkeeper who displays the pen on his shelves and seeks to sell it to customers, it is again different. To return to myself, the pen is also an object of which I grew especially fond because it reminds me of the person who gave it to me.

All these different descriptions are correct: each of them expresses a facet of the object. Yet they are all descriptions of the same object. Hence, one of the main tasks of information science is to find ways to integrate different descriptions of the same object. Some of these descriptions have an ontological basis (the pen has a given length, is made of a given material, etc.); others have an epistemological basis (to my taste the pen is beautiful, I find it useful, etc.).

3: Levels and creativity of reality

Ontologically, the example of the pen teaches us two important lessons: (1) reality is organized into strata (material, psychological, social); (2) these strata are organized into layers (the physical and chemical layers of the material stratum; the intentional and emotive layers of the psychological stratum; the productive, commercial and legal layers of the social stratum). For every (type of) object, there must be a schema (or template) which coordinates and synthesizes the admissible descriptions of it; and for every object, the template that best characterizes it must be elaborated. In the case of my pen, this might be the template "artefact," which implies the fact that the object is above all social in nature, and consequently has social components ("is made by," "for," "costs so much"). However, these dimensions do not account for the ontological structure in its entirety: most if not all of the artefacts also have a material basis, and there may be also components embedded in its structure which evoke psychic components (the *affordances* proposed by Gibson, 1979). An ontology must find a way of coordinating these aspects; a wider description of the structure of an ontology is provided by Poli (2001*a*; 2002).

Most researchers agree that our universe has a single common origin, often described as the "Big Bang." The deep meaning of this thesis is that all the varieties, diversities and structures of the universe are derived. Not only are flowers and universities derived objects, but so too are molecules, and atoms and any particle thereof. All reality – better, all realities – springs from that initial singularity. At this point there are two possibilities: either the whole of reality is somehow, at least implicitly, stored in such a singularity, or reality continuously grows and builds new structures. Besides complexity issues, we simply cannot imagine any way in which the information concerning the whole of reality can be compressed within a singularity. The only remaining option is to accept the idea that reality is creative, and that new realities constantly arise. If so, why should we confine our sense of reality to only a few of its structures? The first structures to have emerged may be basic, in the sense that later structures require former structures, and are built upon them or developed from them. This means that an order of emergence is embedded in the world, and that it unfolds by stages. A theory of the levels of reality is therefore required to clarify many of the still unknown connections between the various levels of emergence. It may also be reasonable to ask whether the deepest and most valuable layers of reality are the older or the newer ones (Poli, 2001*b*).

4: Philosophical contributions to the theory of levels

Not many thinkers have systematically worked on the theory of levels of reality. We may conveniently distinguish the "English-writing" camp from the "German-writing" one. The former comprises, among others, thinkers such as Spencer, Alexander, and Lloyd-Morgan (possibly the most profound among those quoted). Blitz (1992) provides a reliable synthesis of their main contributions. The "German-writing" camp comprises thinkers as relevant as Husserl, Ingarden, Plessner, and Hartmann. Even if some of them are very well known names, there is no academic work summarizing their contributions to ontology in general and to the theory of levels in particular. Some of the ideas advanced by Hartmann have recently been discussed in a conference for the 50 years since his death (see Poli, 2001*d*). A thoroughgoing comparison between the "English" and the "German" camps is nevertheless lacking.

The situation shortly described explains why no generally accepted criterion is available by which to define, describe or at least sketch the idea of level of reality. Among the various proposals that can be put forward, the most general one seems to adopt a categorical criterion: the levels of reality are characterized (and therefore distinguished) by their (ontological) categories.

The next step is to distinguish between universal categories that pertain to reality in its entirety (e.g., whole/part) and categories that pertain solely to one or some levels of reality. We may begin by distinguishing the specific categories of the material world from, for example, those of the psychological world, or from those of the social world. Each of these broad domains displays further categorical articulations (e.g., the categories of physics are not those of chemistry, not those of biology, etc.). If the set-up just described is at least partly plausible, a series of problems immediately arises. With no claim of completeness, these concern:

- forms of dependence among levels;
- forms of autonomy (independence) among levels;
- coordination (integration) among the categories governing some or other level of reality;
- categorical closure (completeness) of levels.

While few ontological contributions are available on these points, we will try to gain some understanding of the problem of levels "the other way round." Instead of starting from the most general (ontological) viewpoint, we will start from the concrete problems posed by bibliographic classification. In short, the latter has to face the same problems of the overabundance of information and its proper coordination. We will see the bibliographical problem from the viewpoint of the categories that can be used for organizing information.

5: Integrative levels in bibliographic classification

In bibliographic classifications, the sequence of main classes has been based mostly on traditional disciplinary divisions. Such are, for example, *Dewey Decimal Classification* (*DDC*)'s 10 main classes; it has been argued that they can be referred back to three superclasses, corresponding to Francis Bacon's tri-partition of knowledge into Memory (History), Imagination (Arts and Literature), and Reason (Philosophy and sciences) – listed by Dewey in the reversed order; these in turn can ultimately be related to Aristotle's tri-partition of philosophy into theoretical, practical, and poietical – again rearranged in order (Dahlberg, 1978, p. 29). Even after the introduction of faceted classification by Ranganathan, main classes remained based on disciplines: *Colon Classification* has 29 main classes, arranged in a somewhat more natural order, from Mathematics and Physics to Sociology and Law. Applied disciplines are intercalated after the corresponding pure ones: Engineering follows Physics, Agriculture follows Botany, etc. Within each main class, subjects are organized according to the *facet formula* typical of that class. It is worth mentioning that there is no mandatory principle for the order of subjects valid through the whole classification, although "later in time," "later-in-evolution," "spatial contiguity," "quantitative measure," "increasing complexity," "canonical sequence," and "literary warrant," in the given order, are acknowledged as good general criteria (Ranganathan, 1967, part F).

The problem of the sequence of the main classes was studied by Henry Evelyn Bliss. His main proposal is the principle of *gradation in speciality*, according to which disciplines dealing with phenomena in a more general and basic way, such as physics, should precede those dealing with more specific phenomena, such as biology, sociology, etc. (Bliss, 1929). The *Bibliographic Classification* proposed by Bliss was subsequently updated and revised according to the theory of facets by members of the Classification Research Group (CRG): the new edition is known as *BC2* (Mills & Broughton, 1977).

As another major reference pattern, CRG had the theory of integrative levels (Spiteri, 1995), as developed by positivistic philosopers Comte and Spencer, and formalized in a more scientific way by Novikoff (1945) and Feibleman (1954). British materialistic scientists J.D. Bernal and Joseph Needham (1976) were especially influential in the transmission of such ideas to CRG, as it has been shown by Justice (2001); anyway, all progress in science at the time suggested a trend towards the interconnection and unity of all knowledge, so that traditional boundaries between disciplines could become inadequate to classify objects (Coates, 1969). Thus the need for a new general classification was comprehended, and the idea of integrative levels could have been a unifying criterion to arrange subjects unambiguously and naturally in a global scheme. Actually, integrative levels are acknowledged as a reference criterion in *BC2*:

> "Gradation is a theoretical order of the subdisciplines of science. It correlates quite strongly with another theoretical order, that of integrative levels, which has proved of considerable value in classification theory in the last decade or so and may be said to give additional point to the theory of gradation" (Mills & Broughton, 1977, section 6.213.32).

A considerable effort was also made by the CRG to build the bases of a brand new general classification based on integrative levels (Classification Research Group, 1969; Foskett, 1970), though no such project was ever completed due to contingent reasons (Foskett, 1978; Austin, 1998; Broughton, personal communication). The theory of integrative levels was introduced by Douglas Foskett, and its possible application to classification was analyzed in detail by Derek Austin (1969*a*, 1969*b*). Austin starts from the 12 natural "laws" of integrative levels, and the 5 related "rules of explanation", as Feibleman formulated them; however he reorganizes them in a new order, possibly more useful for classification purposes (Table 1).

Table 1: Feibleman's laws and rules as resorted by Austin (1969a); in brackets the original position of laws and rules according to Feibleman; captions synthesize Austin's exposition.

Laws to identify and sort levels:
- *The time required for a change in organisation shortens as we ascend the levels. (7)*
- *The higher the level, the smaller its population of instances. (8)*
- *Complexity of the levels increases upward. (2)*
- *Each level organises the level or levels below it plus one emergent quality. (1)*

Laws related to parts of an organization (sublevels):
- *It is impossible to reduce the higher level to the lower. (9)*
- *For an organisation at any given level, its mechanism lies at the level below and its purpose at the level above. (5)*
- *In any organisation the lower level is directed by the higher. (4)*

Rule to determine the right level of representation:
- *The reference of any organisation must be at the lowest level which will provide sufficient explanation. (R1)*

Laws relevant when an organisation is destroyed:
- *In any organisation the higher level depends upon the lower. (3)*
- *A disturbance introduced into an organisation at any one level reverberates at all the levels it covers. (6)*
- *Events at any given level affect organisations at other levels. (11)*

Other laws and rules:
- *An organisation at any level is a distortion of the level below. (10)*
- *Whatever is affected as an organisation has some effect as an organisation. (12)*
- *The reference of any organisation must be to the highest level which its explanation requires. (R2)*
- *An organisation belongs to its highest level. (R3)*
- *Every organisation must be explained finally on its own level. (R4)*
- *No organisation can be explained entirely in terms of a lower or higher level. (R5)*

A number of ideas are implied in Table 1. The first and possibly most relevant one is the following: since higher levels appear later in evolution (7th law), their time of appearance can be used as an objective criterion for establishing the position of levels within their series. Moreover, higher levels are less populated (there are less planets than atoms) (8th law); higher levels are more complex than lower ones (2nd law), because the former organize the latter and give rise to emergent qualities beyond them (1st law).

Austin goes beyond Feibleman, not only by reorganizing the order of his laws, but also by adding new definitions and distinctions (Table 2). Most relevant is the introduction of the difference between *integrative* levels and *aggregative* levels. Aggregates – such as gas mixtures, wolf packs, crowds, research groups – are composed by elements that maintain their identity and can therefore be recognised; on the other hand, the elements that compose integrative levels can no more be individually recognized (Austin, 1969*a*, p. 85). It can be observed that, in many concrete cases, the distinction between integrative and aggregative levels may be difficult to manage: is a coral colony an integrate or an aggregate? Moreover, integration may proceed in steps or there may be a continuum of integrations between parts (the phenomenological concept of fusion comes to one's mind). Complex forms of connections between integrative and aggregative components may occur as well. Austin himself recognizes that "aggregative levels spring from the integrative series" (Austin, 1969*a*, p. 86-87). In spite of all these difficulties, the distinction between integrative and aggregative items refers to a genuine problem.

Table 2: Examples of the various kinds of levels (rearranged from Austin 1969a, p. 86 and 90)

...
integrative level: Elements (e.g. iron, sulphur)
interlevel (e.g. iron and suphur mixed)
  aggregative level: Homogeneous mixtures (e.g. steel)
    disaggregative level (e.g. filings)
integrative level: Compounds (e.g. iron sulphide)
...
integrative levels: [Organisms] (e.g. man)
interlevel (e.g. crowd)
  aggregative level: Families
  interlevel
  aggregative level: Communities

  sublevel: Needs (e.g. metabolic)
  sublevel: Systems (e.g. digestive, respiratory, circulatory)
  sublevel: Organs (e.g. stomach, lungs, artery)
  sublevel: Parts (e.g. lining, sacs, valves)

  disintegrative level (e.g. corpse)
...

Given a certain degree of granularity, aggregates may be distinguished in heterogeneous, such as iron filings and sulphur, and homogeneous, such as steel. For Austin, heterogeneous mixtures (aggregates) are not levels: rather they are *interlevels*, namely some intermediate stage from which it may originate either an aggregative level, consisting of homogeneous mixtures, or an integrative level, such as a chemical compound (Austin, 1969*a*, p. 85-86).

Austin continues claiming that higher levels are formed with elements of lower ones, but they have irreducible special properties not possessed by the single elements (9th law). Many objects can therefore be seen as organizations, in which a given level directs his parts, such as organs of a body, battalions of an army, parts of a car (5th and 4th laws). Unlike Feibleman, Austin argues that such parts are not levels lower than that of the whole: rather they are *sublevels*, originated at the same time of the whole organization, without which they have no sense, not before or after it (1969*a*, p. 87-89). This is another kind of branching from the main series of integrative levels, different from the interlevel branching. It is worth noticing here that functional parts (organs) only appear since the biological level. They exist in higher levels as well, but not in lower ones, such as the physical and chemical. In other words, the category of function is specific of the biological and higher levels. In the same way, the category of purpose (of actions, tools, institutions etc.) characterizes even higher levels. It seems that researchers on classification based on levels have failed to take notice of this.

The properties of a given level must be described in terms of the lowest level needed to explain them (1st rule). Previous stages of evolution within the same level cannot be used as explanations (e.g., the kidney of a toad to explain that of a mammal: these are just successive *species* within the same level (Austin, 1969*a*, p. 89-91)).

Each level depends on the lower ones (3rd law); events at one level can have effects on both higher and lower ones (6th and 11th laws). When any structure of a given level is destroyed, e.g. when an organism dies, the level disintegrates in elements of the lower levels. However, these elements can differ from the original lower level elements which gave birth to the structure ("a dead person is clearly more than a collection of decaying cells"), in keeping some tracks of the higher level from which they have regressed: so they deserve the status of disaggregative interlevel. Anyway, only one *disintegrative* stage can be recognized, not a series of them (Austin, 1969*a*, p. 91-95); the term "disintegrative" is preferred here to "disaggregative" where its meaning is the reverse of "integrative". Sometimes, disintegrative processes can give origin to some new entity, like fossils: this situation has not been considered by Austin.

6: Levels and wholes

Austin's work-in-progress lacks any exact definition of the terms adopted; this would instead be desirable in order to build a more complete theory. As for *integrative* vs. *aggregative* levels, they seem to be distinguishable in that the former are systems in which the whole prevails on their parts, while in the latter the parts are still largely independent from each other; parts in turn can consist of lower integrative levels (see also Poli, 1996). In this respect, Bertalanffy – another reference author for the CRG – points out that systems can be thought of as having been placed along a continuum, from the highly integrated ones, whose behaviour depends on the interactions between all the parts, to the more "mechanic" ones, made of completely independent parts, whose behaviour is described just by the sum of the behaviour of the individual parts (Bertalanffy, 1969).

The last passages make clear that the analyses by Feibleman and Austin mean *level* either as *whole* or as *part*. However, it is worth mentioning that the theory of levels has been intended by most of the scholars who have elaborated its details as a way to improve both the (traditional) theory of being and the theory of wholes. This was the case of Husserl, Ingarden and Hartmann, to mention but a few. The interpretation of "level" as either whole or part runs into serious troubles as soon as psychological and social items are taken into account. Also it comes at a price, namely, it makes impossible to discover whether a properly developed theory of levels, as distinct from the theory of wholes and their parts, has something to add to our understanding of reality. In order to mark as clearly as possible the difference between the theory of wholes and the theory of levels, let us boldly claim that levels are *internal to items but not as their parts* (more details from Poli, 2001*a*; 2001*b*). The last sentence can be taken as the main principle of the theory of levels (as different from the theory of wholes and their parts). Claiming that levels are not parts means that levels are not elements of entities. Therefore, they cannot be detached from their entities.

We have proposed above to adopt a categorical viewpoint. This means that levels are complexes of categories. Levels of reality (ontological levels) result from ontological categories; and levels of representation result from combinations of ontological and epistemological categories. In order to avoid misunderstandings, the expressions "theory of integrative levels" and "theory of integrative wholes" (and variations) should be used as appropriate.

7: Benefits of applying levels to classification

The distinction between integrative levels can serve as a valuable reference in applying facets to specific subjects. For example, Tomlinson notices that Ranganathan's principle of analogy between facets of different disciplines, such as botany and medicine, can be difficult to apply (Tomlinson, 1969*a*). By referring facets to integrative levels, the situation becomes more clear: facets correspond to properties appearing at given levels; while general facets, such as time, space, and energy appear at very early stages in the evolution of the universe, others such as purpose only appear at the mind level, so they can be applied to human activities like medicine but not to spontaneously growing objects like plants. Indeed, such misapplication would be a case of the ontological error of attributing to a given level a category typical of a higher one, an error clearly recognized by Hartmann (1942) and Lorenz (1973). In a classification based on integrative levels, a basic rule should be that the codes for properties emerging at a given level be only "applicable at that and higher numbered levels" (Coates, 1969, p. 21).

Both the order of main classes and the citation order of facets, which as it was seen above are partially arbitrary in traditional classification, would be related to a more precise and objective criterion when based on integrative levels (Coates, 1969, p. 20): indeed, on the basis of Feibleman laws, a level is defined as lower than another, and hence must be expressed by a lower number in classification, if it has appeared before in natural evolution, has a greater population of instances, is organized by higher levels, etc. For example, wooden artifacts should be listed after trees, because they only exist after human technology has modified trees to serve its own purposes.

A classical problem in bibliographic classification is that documents dealing with a given object can be scattered in several points of the scheme, even separated by large distances, according to the disciplines studying them: e.g., sunflowers can be found as a spontaneous plant under Botany, as an ornamental plant under Gardening, as a source of oil under Dairy science, as a subject of pictures under Arts, etc. The first rule of Feibleman, however, allows to state a *place of unique definition* for each phenomenon (Tomlinson, 1969*b*, p. 29), which will be located at the level in which the phenomenon first appears: in the case of sunflowers, that will be the biological level; so the code for the object will be numbered according to that level, and will be reused as a substring in compound concepts at higher levels, such as "sunflowers in 19th century painting".

Unambiguous rules for such place of unique definition are especially relevant for *predictability* of the position of a phenomenon in the scheme (Coates, 1969, p. 20), clearly a major feature for an efficient use of classification by both classifiers and users. This would also allow that different parts of a classification, developed at a given detail for special purposes, be later reconnected in a consistent general scheme, as the structure of all the special parts would be based on shared stable principles – a feature much needed today in order to achieve *interoperability* between great amounts of documents of various origins. Such a possibility of shifting from disciplines to phenomena as the base unit for the structure of classification has been remarked in recent decades by several researchers on classification, among which the editors of *BC2* (Mills & Broughton, 1977, section 5.55), Dahlberg (1978, p. 29-30), Beghtol (1998), Hjørland & Albrechtsen (1999). Gnoli (2005) suggests that phenomena and disciplines could coexist in an "accordion-like" relation within a general scheme.

The approach based on phenomena makes classification more naturalistic (Gnoli, 2004): in this way, a subject is located in the scheme according to its place in the structure of the world, rather than bound to a specific discipline, which in time could develop, change, become more or less fashionable (Gnoli, 2003). In fact, changes in the ways of scientific communication, or of research itself, could make classifications based on disciplines partially inadequate, while they seem less likely to affect in important ways a classification based on the natural order of phenomena.

8: Problems in applying levels to classification

Among the aforementioned researchers concerned with bibliographic classification, two apparently conflicting attitudes can be observed. On one hand some authors, like Farradane (1950), Foskett (1970), and Dahlberg (1978), highlight the search for objective criteria of classification of the content of documents, making it more adherent to knowledge as it is developed by science: e.g., the structure of a classification should be based on levels, because reality itself has a levelled structure. On the other hand some authors also belonging to the CRG, though working in the same direction of a more flexible, efficient and modern classification, appear to be concerned with it only as a practical tool, giving up the hope that it reflect faithfully the structure of reality: in their view, bibliographic classification is a completely different thing from scientific classification. This difference was emphasized in identifying the "Chinese plate syndrome" (CRG, 1978, p. 23): a system allowing to classify books about Chinese plates is not intended to be applied to the classification of Chinese plates themselves. Kyle (1969) plans to divide each main class by a different sequence of properties, according to the pragmatic requirements of the field, much like Ranganathan in *Colon Classification*, so still admitting a prevalence of disciplines on phenomena. Fairthorne's approach is that of an officer at the British aircraft, considering classification as a very technical tool to manage knowledge (Fairthorne, 1961): "because human beings are essentially involved – e.g. they create the documents the scheme is supposed to deal with – any scheme at any time can be no more than a tool" (Fairthorne, 1969, p. 9).

So, which is the true status of bibliographic classification? Actually, the two points of view are not incompatible: documents are concrete instances to arrange in the practical environment of libraries and other institutions, still it is possible that a classification based on consistent and scientific principles make their arrangement and retrieval more effective. In turn, organization of knowledge has always been necessary both to use it and to outline syntheses and connections which are the starting point for further progress: Needham (1969), in his vast survey of the history of science and technology in China, indeed notices that the traditional Chinese term to mean "science" (*kho hsüeh*) literally means "classification of knowledge".

As examples of levels in nature, usually physical, chemical or biological entities are taken. Many authors, however, feel less confident about how to apply their schemes to entities of higher levels, which the CRG calls *artefacts* and *mentefacts* (the latter term being coined by Kyle). According to Coates (1969, p. 21) artifacts, namely technological objects, though reflecting human properties, don't possess them, so their location at the same level of man is not completely satisfying. One would suppose indeed that they form a separate technological level. Huckaby (1972) wrote a strong criticism to the applicability of integrative levels to a general classification scheme, one of the main arguments being that it would be inappropriate for humanistic disciplines. However, Tomlinson (1969*b*, p. 31) was confident that abstract concepts and mentefacts, though requiring further study than the typical examples of concrete entities, would also fit a general scheme by levels. Dahlberg (1978, p. 35) too believes that a simple solution to this problem is adding further levels to those listed by Hartmann and Feibleman. More experimentation would help to clarify the whole question.

Two important categories appear to be the *function* of a biological structure, and the *purpose* of a technological product. However, traditional lists of categories do not include them, and even classificationists applying integrative levels have often failed to recognize them: as it was shown above, their relation to sublevels is not made explicit by Austin; Coates (1969, p. 22) believes that purpose should be a supplementary principle to be used along with integrative levels in deciding the main class order, instead of considering it as a category to be included among the levels themselves.

Another manifest question is that of branching in the sequence of levels. As mentioned above, aggregative levels, sublevels, and disaggregative levels are all different types of branching from the main series of integrative levels. Austin also recognizes that branching can occur between main levels themselves: the prototypical example is that of inorganic bodies such as planets and organic living entities, which both originate from the level of crystals but evolve along two separate lines, into galaxies etc. on one hand and into societies etc. on the other hand (Austin, 1969, p. 83). Furthermore, higher levels can interact between them in complex tangled ways: e.g., limestones appear to be located on the inorganic line, as they are rocks, but they are formed after accumulation of skeletons of living organisms. Similarly, the level of ideas seems to depend both on the mental and the social ones, so suggesting more a rhomboidal than a tree structure.

When trying to represent levels in classification, we are faced with a difficult task: to find ways of expressing such branching and tangled relations in a linear sequence – which is necessary at least to display symbols in alphabetical order and to arrange books in library shelves. The linear sequence may imply a partial loss of the correct structure: e.g., as noticed by Tomlinson (1969*a*, p. 25), putting animals after plants in the sequence does not mean that animals are made of plants, unlike the case of atoms and molecules. Branching structures are treated by several mathematical techniques: bifurcation theory describes systems branching in many dimensions, like it happens when a qualitative novelty occurs in a new level; statistical methods for classification allow to represent similarities by tree-like schemes called dendrograms; coding theory provides ways to order and name the nodes of a tree, including cases of *absorption* where several nodes converge into same node of higher level. Such tools can be considered in order to develop more precise models of structures based on integrative levels (Gnoli & Doldi, *submitted*).

Once an adequate model has been found, it must be reduced to a linear sequence through notation. So the question arises of how notation can represent branching. For instance, one could state that main levels are represented by a first letter (*N* = pluricellular organisms), main branches in them are represented by a second letter (*Nq* = animals), and so on, so reproducing a system similar to that of traditional hierarchical classification, but which also express the relative position of the various levels (Gnoli & Merli, 2005). In doing so, *hospitality* for future developments in knowledge must be kept in mind (Tomlinson, 1969*b*, p. 31): so free symbols should be left available for new levels, both low and high. After some years of research on these lines, Austin (1976) believed that a notation preserving the same code for a given phenomenon through the whole scheme, while offering benefits in machine search and retrieval, could be unsuitable for arranging books on shelves, and that these two tasks should be considered independently.

In a sequence according to integrative levels, the position of the objects of logical, methodological and auxiliary disciplines, such as mathematics, information science, epistemology etc., deserves special discussion. Indeed, as a product of human intellectual activity, they could be listed with higher levels, so taking a high-value code in notation; however, as such disciplines try to find general forms valid for all aspects of the world, their objects could be rather considered as universal properties and placed before all levels, or in very low levels. This problem is identified by Coates (1969, p. 22) too. The question is related to whether logic and mathematics are only human constructions, or they reflect real properties of the world as claimed by Platonism. Most bibliographic classifications list bibliographic and auxiliary disciplines before all other classes; however, this looks more a self-referential bias than an ontological choice, as mathematics instead is listed within the sequence, before physics, as one of the "scientific" disciplines.

Finally, once the main sequence of classes has been defined according to integrative levels, rules must be given about how to compose notation for complex concepts. Relations between objects occurring at different levels can be of various nature. We could distinguish at least between substantial and occasional relations.

9: Conclusion

As has been shown, the idea of levels has appeared in various contexts as a promising model for such wide fields as ontology, epistemology, and knowledge representation. However, it has not coalesced in a unitary school; rather it is spread into different streams, so that a full analysis of its aspects, problems, and potential of explanation is still to be completed.

Furthermore, the application of the levels-model to the different fields, of course, implies different specific problems, such as that of representing branching in classification. This does not exclude the fact that problems in application to a given field can teach lessons which can be fruitful for other fields: representation issues can stimulate clarification of ontological questions, and inversely, ontology can offer more robust and lasting foundations for knowledge representation.

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